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Access Challenges and Implications for Airpower in the Western Pacific

Eric Stephen Gons

This document was submitted as a dissertation in May 2010 in partial fulfillment of the requirements of the doctoral degree in public policy analysis at the Pardee RAND Graduate School. The faculty committee that supervised and approved the dissertation consisted of Bart Bennett (Chair), Roger Cliff, and John E. Peters.
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Since WWII, U.S. military successes have depended on air superiority and air dominance. Successive generations of fighters have wrestled air superiority from each adversary in turn, enabling every other use of airpower, and indeed, military power in general. The last American killed by a foreign aircraft died in 1953, and U.S. air superiority has enabled every other airpower capability – ISR, C2, interdiction, strike, close air support, etc. U.S. air superiority has also given land and naval forces unprecedented flexibility and security. U.S. warfighting has evolved with air dominance as an assumption, enabling positioning of overwhelming forces at large, secure bases and staging areas.

There is a distinct possibility that this assumption might fail in a vital theater of interest – the western Pacific. Chinese military modernization has proceeded rapidly, giving the PLA a formidable array of modern weaponry, including advanced 4th-generation fighters, the latest integrated air defenses, and a huge arsenal of conventional ballistic missiles. Chinese military modernization has focused on finding an “indirect approach” to blunt or neutralize the hallmark of U.S. military power, airpower. This report examines whether such efforts may prove successful, and if so, the extent to which U.S. airpower suffers in a notional Taiwan air defense scenario.

This dissertation examines the risk of U.S.-China conflict based on a variety of theoretical works on conflict, applied to the U.S.-China relationship. Following this examination, and finding that the U.S.-China relationship does include elements of risk, the dissertation examines the implications of anti-access weapons on USAF sortie generation. The dissertation develops a simple sortie-generation model and air combat framework, using open-source data to estimate the forces that the USAF and the PLAAP can bring to bear, and predicts the results

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of air combat between two forces of dissimilar performance and quantity. Finally the dissertation examines options for increasing USAF performance in the face of antiaccess weapons, which includes a methodology to assess the effectiveness of strike employed to achieve air superiority.

This dissertation includes assumptions and omissions intended to focus its scope. These limitations are fully caveated in the introduction, in the conclusions, and as they occur throughout the dissertation. This research should be of interest to anyone involved with defense policy regarding USAF modernization and force structures or defense policy regarding the U.S. security posture in the western Pacific.
### Availability of Airbases

- 6. Discussion of Alternatives
  - Introduction
  - Implications of Continuing the Status Quo
  - Option 2, Hardening Close-in Airbases
  - Option 3, Increasing Maximum-on-Ground And Deployment to Andersen AFB
    - Introduction
    - Hypothetical Beddowns
    - A Potential Use for Andersen Northwest Field
  - Option 4, Options for Increasing the On-station Missile Magazine
    - Introduction
    - Externally Loading F-22s
    - Cooperative Targeting
    - Standoff Air Superiority
    - Effect of Alternatives on Operations in the Western Pacific
  - Option 5, Degrading PLA Sortie Generation
    - Introduction
    - Active Defenses
    - PLA Airbase Passive Defenses
    - Degrading Operating Surfaces
    - Attacking Parked Aircraft
    - Effects of Proposed Attacks
  - Summary of Options
  - Combination Approach for Overcoming Access Challenges

### Conclusions

- Political Analysis and the Risk of Conflict
- Antiaccess Challenges and Implications
Figure 1 China’s Rising Defense Budget in 2002 RMB
Figure 2 China and U.S. National Capabilities, 1991-2001
Figure 3 Partial Aerial View of Kadena AB
Figure 4 PLA Missile Ranges
Figure 5 Footprint of a Hypothetical Submunition-Armed DF-15
Figure 6 DF-15 Footprint at a Portion of Kadena AB
Figure 7 Distances from Selected Airbases to the Taiwan Strait Center Point
Figure 8 Desert Storm vs. Pacific Theater (same scale)
Figure 9 USAF Combat Radii and Inventory
Figure 10 Flanker/F-22 Ratio for a Range of F-22 Deployments
Figure 12 Force Ratios for a Variety of Beddown Possibilities
Figure 13 Pictorial Combat Framework Representation
Figure 14 Maintenance Sensitivity Analysis
Figure 15 Increased F-22 Beddown Sensitivity Analysis
Figure 16 U-2 Shelter at RAF Alconbury
Figure 17 Aerial View of Andersen APB
Figure 18 Andersen NWF 2002 Aerial Photograph
Figure 19 Overgrowth and Encroachment on Andersen NWF taxiway
Figure 20 Raptor with External Armament
Figure 21 Boeing Illustration of Proposed B-1R
Figure 22 Vympel R-37 and Novator R-172
Figure 23 Notional Missile Range Requirement
Figure 24 Irbis-E 187 nm Detection Radius on 3m² RCS Target
Figure 25 BVR Missiles of the World, Weights and Ranges
Figure 26 Predicted Pattern of BVR Range and Weight
Figure 27 BVR Missiles with Early Generations Shown
Figure 28 Vympel R-77 with Ramjet for Extended Powered Flight
Figure 29 MBDA Meteor
Figure 30 NCADE Schematic Shows the Stages
Figure 31 Notional Depiction of the R-74AB-PD
Figure 32 Cooperative Engagement
Figure 33 Force Ratios with Increased Missile Magazine Options
Figure 34 Force Options and Raid Stopping Potential .................153
Figure 35 JASSM-ER (left) and CALCM (right) Coverage of PLA Airbases 156
Figure 36 PLA Quzhou in the Nanjing MR ..............................157
Figure 37 Shelters at PLA Fuzhou ....................................158
Figure 38 Shelters at PLA Zhangzhou ..................................159
Figure 39 Aerial View of PLA Feidong ...............................160
Figure 40 Primary Entrance to Underground Aircraft Shelter at PLA Feidong .....................................................161
Figure 41 Entrance to Underground Shelter at a Similar Airbase ......162
Figure 42 Secondary Underground Structure ..........................162
Figure 43 Crater Types ..............................................166
Figure 44 Cuts Required to Shut Down PLA Feidong .................167
Figure 45 Crater Sizes and Types ....................................168
Figure 46 TLAM-D Coverage on PLA Changsha Huanghua .........171
Figure 47 CALCM Lethal Radius vs. a Hardened Aircraft Shelter ...172
Figure 48 View of Rubble and Undamaged Inner Door at Slatina AB in Kosovo ......................................................175
Figure 49 Aerial View of GBU-28 Strike at Slatina AB in Kosovo. 175
Figure 50 Effects of Standoff Attacks on PLAAF/PLANAF ability to sustain Notional CAP – Current Hardening Features ...........181
Figure 51 Effects of Standoff Attacks on PLAAF/PLANAF ability to sustain Notional CAP – Upgraded HAS ............................182
Figure 52 Pictorial Combat Model Representation .....................222
Figure 53 Chinese HAS at PLA Suixi, a Su-30 base ................228
Figure 54 HAS as a Circular Target ..................................228
Figure 55 Overpressure and Distance .................................229
Figure 56 Lethal Radius of a CALCM vs. a HAS ......................231
Figure 57 Distance from Aimpoint a CALCM must land in order to destroy HAS target ...............................................231
Figure 58 TLAM-D Footprint on Revetted Dispersal Parking at Changsha Huanghua AB ..........................236
TABLES

Table 1 Historical U.S. and Chinese GDP...............................14
Table 2 Projected U.S. and Chinese GDP Growth..........................14
Table 3 Nominal U.S.-China Trade, 1980-2005.............................27
Table 4 Empirical Attributes of War-Prone Dyads Applied to the U.S.-China Dyad ...................................................29
Table 5 Postulated Contingency Flanker Bases..........................88
Table 6 Sortie Rates and Airbase Contributions to Steady State CAP....90
Table 7 Kill Potential of 6 F-22s vs. 36 Red Aircraft....................102
Table 8 Expected Losses in a 6 on 12 WVR Engagement..................105
Table 9 Losses to High-Value Aircraft from Leakers...................106
Table 10 PLAAP Flanker Beddown with no Contingency Locations.......111
Table 11 Deployments Required to Meet Selected Force Ratios..........123
Table 12 Estimated Expeditionary Assets Required to Bring Andersen NWF MOG to 150 ..................................................127
Table 13 Selected U.S. SAMs..............................................139
Table 14 Range and Weight Options....................................149
Table 15 On-Station Missile Magazine...................................152
Table 16 Weapons Required to Shut Down one Superhardened Airbase....169
Table 17 Approximate Kill Probabilities for a Single Standoff Weapon.172
Table 18 Pk for CALC/Ms Engaged by Air Defenses.....................173
Table 19 PLAAP Airbase Contributions to Sortie Generation.............178
Table 20 Summarized Alternatives.....................................186
Table 21 Standard Times to Complete Aircraft Turnaround Actions.....204
Table 22 Relevant Aircraft Data...........................................206
Table 23 Maintenance Capacity, Wait and Cycle Times....................212
Table 24 Postulated Flanker Bases in a Contingency....................217
Table 25 PLAAP Airbase Contributions to Sortie Generation............220
Table 26 Standoff Weapons’ Lethal Radii and Accuracy..................230
Table 27 Approximate Kill Probabilities for a Single Standoff Weapon.232
Table 28 Kill Probabilities for CALC/Ms Engaged by Air Defenses......234
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While I cannot overstate the impact of the help I have received from others, I alone bear responsibility for any errors or omissions found in this dissertation.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AB</td>
<td>Airbase</td>
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<tr>
<td>AESA</td>
<td>Active Electronically Scanned Array</td>
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<td>AEW&amp;C</td>
<td>Airborne Early Warning and Control</td>
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<td>AFB</td>
<td>Air Force Base</td>
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<td>AMRAAM</td>
<td>Advanced Medium-Range Air-to-Air Missile</td>
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<td>AO</td>
<td>Area of Operations</td>
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<td>ASAT</td>
<td>Anti-Satellite</td>
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<td>ASBM</td>
<td>Anti-Ship Ballistic Missile</td>
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<td>ASCM</td>
<td>Anti-Ship Cruise Missile</td>
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<td>AWACS</td>
<td>Airborne Warning</td>
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<td>BEAR</td>
<td>Base Expeditionary Airfield Resources</td>
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<td>BVR</td>
<td>Beyond Visual Range</td>
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<td>C2</td>
<td>Command and Control</td>
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<td>CALCM</td>
<td>Conventional Air-Launched Cruise Missile</td>
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<td>CAP</td>
<td>Combat Air Patrol</td>
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<td>CEP</td>
<td>Circular Error Probable</td>
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<td>CINC</td>
<td>Comprehensive Index of National Capabilities</td>
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<td>CONOP</td>
<td>Concept of Operations</td>
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<tr>
<td>COW</td>
<td>Correlates of War</td>
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<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<td>DoD</td>
<td>Department of Defense</td>
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<tr>
<td>DPP</td>
<td>Democratic Progressive Party</td>
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<td>DSMAC</td>
<td>Digital Scene-Matching Area Correlation</td>
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<td>EMP</td>
<td>Electromagnetic Pulse</td>
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<td>EW</td>
<td>Electronic Warfare</td>
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<td>FOD</td>
<td>Foreign Object Debris</td>
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<td>G</td>
<td>Gravitational Acceleration</td>
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<td>G8</td>
<td>Group of Eight</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>HAS</td>
<td>Hardened Aircraft Shelter</td>
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<td>Symbol</td>
<td>Definition</td>
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<td>----------</td>
<td>---------------------------------------------------------------------------</td>
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<tr>
<td>HDI</td>
<td>Human Development Index</td>
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<td>ICBM</td>
<td>Intercontinental Ballistic Missile</td>
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<td>IRBM</td>
<td>Intermediate Range Ballistic Missile</td>
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<tr>
<td>IRST</td>
<td>Infrared Search and Track</td>
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<tr>
<td>ISR</td>
<td>Intelligence, Surveillance, and Reconnaissance</td>
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<tr>
<td>JASSM</td>
<td>Joint Air-to-Surface Standoff Missile</td>
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<tr>
<td>JASSM-ER</td>
<td>JASSM - Extended Range</td>
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<td>JDAM</td>
<td>Joint Direct Attack Munition</td>
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<td>JSOW</td>
<td>Joint Standoff Weapon</td>
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<tr>
<td>JSTARS</td>
<td>Joint Surveillance Target Attack Radar System</td>
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<tr>
<td>JTIDS</td>
<td>Joint Tactical Information Distribution System</td>
</tr>
<tr>
<td>KTAS</td>
<td>Knots True Airspeed</td>
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<tr>
<td>LO</td>
<td>Low-Observable</td>
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<tr>
<td>LST</td>
<td>Landing Ship, Tank</td>
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<tr>
<td>MALI</td>
<td>Miniature Air-Launched Interceptor</td>
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<tr>
<td>MANPADS</td>
<td>Man-Portable Air Defense System</td>
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<tr>
<td>MCAS</td>
<td>Marine Corps Air Station</td>
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<tr>
<td>MOG</td>
<td>Maximum On-Ground</td>
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<tr>
<td>MR</td>
<td>Military Region</td>
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<tr>
<td>NATO</td>
<td>North American Treaty Organization</td>
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<tr>
<td>NM</td>
<td>Nautical Miles</td>
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<tr>
<td>NWF</td>
<td>(Andersen AFB) Northwest Field</td>
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<tr>
<td>OAF</td>
<td>Operation Allied Force</td>
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<td>OEF</td>
<td>Operation Enduring Freedom</td>
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<td>OIF</td>
<td>Operation Iraqi Freedom</td>
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<td>OSD</td>
<td>Office of the Secretary of Defense</td>
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<tr>
<td>PK</td>
<td>Probability of a Kill</td>
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<tr>
<td>PLA</td>
<td>People’s Liberation Army</td>
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<td>PLAAF</td>
<td>People’s Liberation Army Air Force</td>
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<td>PLAN</td>
<td>People’s Liberation Army Navy</td>
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<tr>
<td>PLANAF</td>
<td>People’s Liberation Army Navy Air Force</td>
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<tr>
<td>POL</td>
<td>Petroleum, Oil, and Lubricants</td>
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<tr>
<td>PPP</td>
<td>Purchasing Power Parity</td>
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<td>PRC</td>
<td>People’s Republic of China</td>
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<td>Symbol</td>
<td>Definition</td>
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<td>RAF</td>
<td>Royal Air Force</td>
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<td>RCS</td>
<td>Radar Cross-Section</td>
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<td>RMB</td>
<td>Renminbi</td>
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<td>ROC</td>
<td>Republic of China</td>
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<td>ROCAF</td>
<td>Republic of China Air Force</td>
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<td>ROK</td>
<td>Republic of Korea</td>
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<td>RPG</td>
<td>Rocket-Propelled Grenade</td>
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<td>SAM</td>
<td>Surface-to-Air Missile</td>
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<td>SEAD</td>
<td>Suppression of Enemy Air Defenses</td>
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<td>SOF</td>
<td>Special Operations Forces</td>
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<td>SSGN</td>
<td>Nuclear-Powered Cruise Missile Submarine</td>
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<tr>
<td>TEL</td>
<td>Transporter-Erector-Launcher</td>
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<tr>
<td>TBM</td>
<td>Theater Ballistic Missile</td>
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<tr>
<td>TBMD</td>
<td>Theater Ballistic Missile Defense</td>
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<tr>
<td>TERCOM</td>
<td>Terrain Contour Matching</td>
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<td>TLAM</td>
<td>Tomahawk Land-Attack Missile</td>
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<td>UN</td>
<td>United Nations</td>
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<td>U.S.</td>
<td>United States</td>
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<td>USAF</td>
<td>U.S. Air Force</td>
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<td>USN</td>
<td>U.S. Navy</td>
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<tr>
<td>VLO</td>
<td>Very-Low Observable</td>
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<tr>
<td>WVR</td>
<td>Within Visual Range</td>
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</table>
1. INTRODUCTION

Since WWII, U.S. military successes have depended on air dominance. Successive generations of fighters have wrestled air superiority from each adversary in turn, enabling every other use of airpower, and indeed, military power in general. The last American killed by a foreign aircraft died in 1953,\(^2\) and U.S. air superiority has enabled every other airpower capability – ISR, C2, interdiction, strike, close air support, etc. U.S. air superiority has also given land and naval forces unprecedented flexibility and security. U.S. warfighting has evolved with the precondition of air dominance, enabling the deployment of overwhelming forces at large, secure bases and staging areas.

There is a distinct possibility that this assumption might fail in a vital theater of interest – the western Pacific. Although the United States and China have many common interests, the relationship includes elements of risk. U.S. deterrence should play a strong role in influencing China and encouraging it to develop as a status-quo power – the ability to protect U.S. strategic interests militarily is vital even if we do not expect to actually exert military force. Indeed, it is the ability to fight and win which reassures us that we can maintain the peace.

Chinese military modernization has proceeded rapidly, giving the PLA a formidable array of modern weaponry, including advanced 4th-generation fighters, the latest integrated air defenses, and a huge arsenal of conventional ballistic missiles. Chinese military modernization has focused on finding “indirect approaches” to blunt or neutralize the hallmarks of U.S. military power, one of which is airpower. This report examines whether such efforts may prove successful, and if so, the extent to which the assumption of air dominance may suffer in a notional defense of Taiwan scenario. In order

\(^2\) Dudney, “Air Supremacy in a Downdraft,” p. 2.
to assess how the U.S. security posture in the western Pacific may change, we need to consider several research questions:

- What are the prospects for armed conflict between the United States and China in the foreseeable future?
- If armed conflict occurs, to what extent will Chinese antiaccess capabilities affect USAF warfighting?
- If the USAF is hindered in deploying full combat power to the theater, to what extent will the USAF be able to meet hypothetical operational goals?
- What alternatives may mitigate antiaccess challenges?

**WHAT ARE THE PROSPECTS FOR ARMED CONFLICT BETWEEN THE UNITED STATES AND CHINA?**

To analyze the possibility of U.S.-China conflict, this research turns to the international relations literature, considering two main perspectives on conflict generation. One is the historical change process, for which Robert Gilpin’s *War and Change in World Politics* is the exemplar.\(^3\) This perspective explains that interstate conflict arises as a result of hegemonic states confronting the diminishing returns to expansion, consequently weakening and being replaced by rising challengers. The other perspective is empirical, which examines the linkages between conflicts and observable, measurable characteristics of states and relationships between states (e.g. form of government, industrial output, proximity between states in a dyad).\(^4\)

**IF ARMED CONFLICT OCCURS, TO WHAT EXTENT WILL CHINESE ANTIACCESS CAPABILITIES AFFECT USAF WARFIGHTING?**

In order to project power, air forces require secure bases from which to operate. The history of attacking an enemy’s airbases is almost as old as the history of military aviation itself.\(^5\) The logic of

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\(^4\) The term “dyads” refers to a pair of states whose war-proneness is analyzed.

\(^5\) The first recorded air attack occurred 24 Aug 1914 when Capt H.C. Jackson and Lt. E. L. Conran threw several bombs out of the cockpit at (Continued on the next page).
attacking airbases is sound: aircraft on the ground present
concentrated, immobile, vulnerable targets – and can be destroyed more
easily than aircraft in flight.

The USAF has faced threats to its airfields before. During the
Cold War the United States built a network of airfields which
incorporated extensive hardening. Hardening included concrete shelters
for aircraft and personnel, redundant operating surfaces, rapid runway
repair capabilities, and survivable command and control. These measures
were necessary given the extent of Soviet capability to attack these
facilities. USAF facilities in other theaters generally faced lesser
threats, and consequently are less able to withstand attack. Yet the
conventional threats against these less-survivable facilities in the
western Pacific have become at least as daunting as those in Cold War
Europe.

China has a range of force options to keep the USAF out of its
immediate proximity. In the diplomatic and coercive arena, China could
attempt to split the United States from its allies. If this occurred,
the closest sovereign U.S. territory is Guam. Note that splitting
alliances has a long history in Chinese strategic thought. Fixed wing
aviation, special operations forces, and cruise missiles can physically
threaten U.S. airbases. But the most potent threats result from the
confluence of submunitions and ballistic missiles. Ballistic missiles
are difficult to intercept, and their short flight time does not give
enough warning to evacuate aircraft and shelter personnel. Coupling
ballistic missiles with submunitions would allow an attacker to cover
huge areas with relatively few weapons.

Chapter 2 will examine the options China has been developing to
exclude the USAF from vital airbases in the western Pacific.

three German aircraft they spotted parked near Tournai, Flanders while
on a reconnaissance mission. John Kreis, Air Warfare and Airbase
pp. 5-6.
IN THE FACE OF ANTIACCESS THREATS, WILL THE USAF BE ABLE TO MEET OPERATIONAL GOALS?

This research examines the result of Chinese antiaccess capabilities in the context of a Taiwan scenario. In the event of PRC aggression against Taiwan, if the United States chose to come to Taiwan’s aid, operational goals would presumably include the air defense of Taiwan and eventually establishing air superiority over the island.

The geography of the western Pacific means that the United States would only be able to operate efficiently from a few airbases. Unfortunately, the airbases suitable for fighter operations are close enough to mainland China to invite attack. Thus, the United States may have to rely on fighter operations from further afield, like Andersen AFB. This study uses a sortie generation model to examine the potential force that could be delivered from Andersen AFB, and compares this to the sortie generation capability of China’s fourth-generation fighters. We will see how fighting greatly outnumbered can present problems even for qualitatively dominant fighters like the F-22.

WHAT ALTERNATIVES MAY MITIGATE ANTIACCESS CHALLENGES?

China’s antiaccess capabilities would pose serious challenges to the USAF in the region, but the USAF has some options to mitigate some of this challenge. This research examines a few of these options – hardening, increasing capacity at standoff airbases, degrading PLA sortie generation through strikes, and a concept for standoff air superiority. There is likely no “magic bullet” to completely restore the safe, secure basing that the USAF has enjoyed since the end of the Cold War. However, some of these options in combination could go a long way to restoring the U.S. ability to achieve operational goals in defense of Taiwan, avoid losing influence in the western Pacific, and preserve U.S. power and prestige worldwide.

CAVEATS

This dissertation is intended to be limited in scope and includes some deliberate omissions in an attempt to focus the military analysis on the hypothetical air war. Also, certain aspects of a hypothetical
U.S.-China conflict over Taiwan are treated lightly due to the paucity of information available.

Consequently, it is important that the reader recognizes these limitations. Also, any follow-on work should strive to include some of the issues below to create the whole picture.

This dissertation focuses on the air war, and does not rigorously examine either the naval or ground aspects of a hypothetical conflict. Clearly, prevailing or failing in the air conflict would not directly or necessarily translate to prevailing or failing to achieve broader objectives. In fact, the U.S. has important capabilities in other military domains, not to mention other instruments of national power, that would be very important to consider in a broader analysis of a hypothetical U.S.-China conflict. This dissertation intentionally omits many of these factors in order to focus on, call attention to, and offer alternatives to improve the viability of U.S. airpower in the western Pacific.

The air war would only be one aspect of an armed conflict between the U.S. and China. A conflict would take place in air, space, cyber, ground, and naval domains; would most likely involve other nations’ forces; and would involve other aspects of U.S. national power. A broader analysis would need to discuss these aspects and would need to include a fuller examination of Chinese political military calculus than is found herein. This would include, but would not be limited to, how China might transition along the spectrum of diplomatic and military coercion, how China might escalate and de-escalate, and how China might manage the appearance of its actions to domestic and international audiences. A full understanding of these factors is absolutely necessary to crafting an effective and flexible U.S. strategy; the military effort (and air effort) would only be one component of that strategy.

Turning to the air campaign, this analysis does include several limitations which subsequent analyses could improve. In some cases these limitations stem from the intentional isolation of specific variables; in other cases they stem from sparse or opaque information. A broader analysis would benefit from a fuller treatment of the Republic
of China Air Force (ROCAF); a deeper understanding of layered Chinese IADs and their implications on aircraft survivability; the interplay of Taiwanese, U.S. Army, and U.S. Navy air defenses; and more complete F-22 sortie generation data.

Despite these limitations, this dissertation is able to generate important insights that should be of interest to anyone concerned with defense policy in the western Pacific. To as great an extent possible, the analysis herein has been structured so that its conclusions are robust to incomplete data and imperfect assumptions. The scope of the conclusions has been limited so as to be germane to the analysis actually performed.
2. POLITICAL BACKGROUND – PROSPECTS FOR U.S.-CHINA CONFLICT

INTRODUCTION

It is far from clear that China’s emergence as a major power will precipitate conflict with the United States. Some observers have called predictions of a menacing China overblown. Others point less to historical determination, but still maintain that economic interdependence will promote peaceful interaction.6 However, this same economic dynamic has also been claimed to be predictive of conflict – China’s gains from trade will be relatively larger than its neighbors, and its economic power will allow it to bully and dominate its neighbors.7 Khalilzad and others paint a picture of a stronger and more assertive China.8 Thus, there is no clear consensus about the implications of China’s rise. This chapter will explore the prospects for violent conflict between China and the United States, with an emphasis on Taiwan as the flashpoint. This discussion will illuminate the risks and encouraging elements in the U.S.-China relationship through an application of hegemonic change and empirical explanations for conflict generation.

Robert Gilpin paints a picture of rising states challenging the security order sponsored by declining states as the genesis of great power war.9 We will explore how well the United States and China fit into this process, and highlight the developments that could make the United States and China more or less war-prone.

A wealth of empirical studies have shown which structural factors are correlated with war. Geller and Singer have synthesized these works, discussing factors correlated with the war-proneness of states,

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9 Gilpin, War and Change in World Politics.
of dyads (pairs of states), of regions, and of international systems.\textsuperscript{10} Testing the U.S.-China relationship against these factors is revealing of risks and opportunities in the relationship.

After exploring structural factors, we will turn to a discussion of why Taiwan is the most likely flashpoint. Discussion will focus on the work of Bush and O’Hanlon,\textsuperscript{11} with a consideration of crisis management.

We will see that China’s rise creates opportunities for peace and risks of conflict. Effectively managing U.S.-China relations requires emphasizing factors that encourage peace and hedging against conflict by enhancing defense and reducing weaknesses.

\section*{AN INTRODUCTION TO HEGEMONIC CHANGE}

Robert Gilpin, in \textit{War and Change in War Politics}, argues that international political change is a “continuous historical process.”\textsuperscript{12} In it, Gilpin examines international change according to the following framework:

\begin{itemize}
  \item The international system is stable if no state believes it is profitable to change the system.
  \item A state will attempt to change the international system if expected benefits exceed expected costs.
  \item A state will attempt to change the system through territorial, political, or economic expansion until the expected marginal benefit of further expansion is less than the expected marginal cost of further expansion.
  \item The costs of maintaining the status quo tend to rise more rapidly than a state’s economic capacity to support the status quo.
  \item If disequilibrium is not resolved, the system will be changed and a new distribution of power established.
\end{itemize}


\textsuperscript{12} Gilpin, \textit{War and Change in World Politics}, p. 45.
This set of conditions leads to a continuous process where a state with growing power feels compelled to challenge the old hegemon for control of the international system, displaces the old hegemon and expands its own hegemony until costs exceed benefits, subsequently has trouble maintaining the status quo, and is finally challenged and displaced by a more vibrant power.\textsuperscript{13}

Gilpin notes many mechanisms of change in the international system - but “the most destabilizing factor is the tendency in an international system for the powers of member states to change at different rates because of political, economic, and technological developments.”\textsuperscript{14} Small and incremental changes are usually accommodated within the context of the system, but large changes and incremental changes over time may result in disequilibrium.

But what constitutes the “system” that Gilpin repeatedly references? The theoretical foundation for the 'war as a process' school of thought is solidly realist, which would imply a lack of a formal international system. Gilpin concedes that relations between states are formally anarchic, in that there are no firm rules that govern states. However, he argues that although largely anarchic, an international system exercises at least some element of control on relations between states.\textsuperscript{15}

Gilpin’s construct of the international system includes three elements: the distribution of power in coalitions, the hierarchy of prestige, and the rights and rules that govern interactions among states. The distribution of power in coalitions is analogous to neorealists balancing and bandwagoning - but rather than aligning to achieve a strict balance of power, Gilpin acknowledges that leading a system of coalitions is a way that a hegemonic state exerts control over international relations.\textsuperscript{16}

\begin{flushleft}
\textsuperscript{13} Gilpin, War and Change in World Politics, p. 10-11. \\
\textsuperscript{14} Gilpin, War and Change in World Politics, p. 13. \\
\textsuperscript{15} Gilpin, War and Change in World Politics, p. 27. \\
\textsuperscript{16} Gilpin, War and Change in World Politics, p. 28. 
\end{flushleft}
A second characteristic of the international system by which hegemonic states exert influence or informal control is the hierarchy of prestige. Prestige, in the context of states, is a reputation of power. It is analogous to authority or legitimacy. While not necessarily measurable, prestige is expressed in the context of its use. Being on top of the hierarchy of prestige allows a hegemon to exert considerable sway over international affairs without having to resort to violence.\textsuperscript{17}

The final characteristic of the international system described by Gilpin is the set of rights and rules that govern state interactions. This set includes tacitly acknowledged spheres of influence, rules for diplomacy, standard commerce and trade practices, multilateral treaties, and international law.\textsuperscript{18} Though Gilpin does not treat them directly (though many may be inferred from his inclusion of “multilateral treaties”), an important part of the day-to-day functioning of the international system now includes non-governmental organizations, trade bodies, and other institutions that help regulate the international system.

The international system thus defined, we may move on to equilibrium. The system is in equilibrium when no state simultaneously has the incentive and the capacity to change the system. While of course at all times any state may wish to change the system to their benefit, in equilibrium none will have the capacity to challenge the hegemon and do so. In other words, in equilibrium the expected costs of attempting to change the system exceed the expected benefits. In disequilibrium a challenger state possesses the capacity and incentive to attempt system change. The principal mechanism of change is war – a hegemonic war where leadership of the international system is at stake.\textsuperscript{19}

Now we shall explore the process of hegemonic change as it applies to the current situation between the United States and China and

\textsuperscript{17} Gilpin, War and Change in World Politics, p. 32.
\textsuperscript{18} Gilpin, War and Change in World Politics, pp. 34-36.
\textsuperscript{19} Gilpin, War and Change in World Politics, pp. 197-198.
determine whether China and the United States are headed towards hegemonic conflict.

**Applying Hegemonic Change to the United States and China**

The United States has fit Gilpin’s criteria for a leader of the international system. Regarding the system of coalitions, the United States led the victors of WWII, bankrolling much of the allied war effort. In the aftermath, the United States led the western bloc of nations aligned against the Soviet bloc. The United States was the surviving power of the Cold War, and has subsequently joined nations together in policing the world order, for example against aggression in Iraq in 1991 and against ethnic cleansing in the former Yugoslavia in 1999.

The ability of the United States to organize much of the Western world into coalitions with common purpose also speaks to Gilpin’s second characteristic of the international system: the hierarchy of prestige. Since the end of WWII, the United States has been synonymous with leadership and primacy in world affairs.

During this time the United States sponsored and informally led many of the multilateral institutions that characterize the “set of rules and expectations” element of Gilpin’s international system – institutions like the United Nations, the World Trade Organization, and the World Bank and International Monetary Fund (although Europe is traditionally responsible for appointing the president of this organization). Indeed, these institutions are largely dominated by the industrial world (G8) led by the United States.

While the United States currently fits the criteria for hegemony, there are signs that cracks are forming in the U.S. power base. Prestige is eroding as much of the world sees American “adventurism” as an illegitimate abuse of power. “Coalitions of the willing” are growing ever smaller. The key structural basis for eroding hegemony is Gilpin’s assertion that the costs of maintaining the system rise faster than the
hegemon’s capacity to bear those costs. Many of the phenomena supporting that pattern are evident today:

- The leader of a coalition tends to invest more than other members, yet reaps proportionally less reward. The U.S.-led bloc was victorious in the Cold War, but at the cost to the United States of a substantial portion of the national debt, whose total financing demands about 2% of GDP a year.

- As economies mature and grow less rapidly, consumption rises, investment tends to decrease, and the economy stagnates. We now see the U.S. real savings rate at zero or below.

- Governments face increased pressure for social services, stretching the budget, and allocating resources away from defense and maintenance of hegemony. We now see a U.S. budget dominated by social services, health care, debt financing, and consumption demands – limiting U.S. ability to pay for security commitments.

- Security problems multiply faster than the ability to confront them. To whit, the United States is committed in the Middle East, draining over $2 billion a week in treasure, while the military finds itself less prepared to deal with challenges in other areas of the world. While the forces required for current conflicts are different from those required for western Pacific security, the degree of national and budgetary distraction still lessens the military’s capacity to respond to new threats.

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20 Gilpin, War and Change in World Politics, p. 186.
21 This is the freeriding problem described in Gilpin, War and Change in World Politics, p. 193.
23 Gilpin, War and Change in World Politics, p. 160.
24 Gilpin, War and Change in World Politics, p. 188.
The other element of hegemonic change is the existence of a challenger able to displace the old hegemon. Recent developments, especially Chinese economic growth, make Chinese potential to challenge the United States for control of the international system a serious possibility.

In the modern era, economic might is the basis of military and political power. As such, it is a convenient measure of the capacity of a country to force change. Differential growth in power is the primary destabilizer of the international system, and China’s economy has been growing remarkably quickly, averaging 9.7% annualized growth over the period of 1979-2005.26 Over the same period, the United States has grown roughly 3% annually.27

Table 1 compares the relative sizes of the U.S. and Chinese economies. Note that U.S. economic preponderance over China is a relatively recent phenomenon and that its magnitude has been diminishing since 1973. China’s meteoric growth has been fuelled in part by U.S. consumption, and facilitated by the economic opening engineered by Deng Xiaoping. China’s economic reinvention unleashed the productive labor of millions of people formerly shackled by communism. If current trends continue, U.S. economic superiority may have been a fleeting phenomenon (see Table 2). Indeed, the Congressional Research Service claims that it is “highly likely that China at some point will overtake the United States as the world’s largest economy.”28 One projection, by Global Insight, has this occurring (in purchasing power parity terms) by 2013.

Table 1
Historical U.S. and Chinese GDP\textsuperscript{29}

<table>
<thead>
<tr>
<th>United States</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP % of world GDP</td>
<td>GDP % of world GDP</td>
</tr>
<tr>
<td>% of world GDP</td>
<td>GDP % of world GDP</td>
</tr>
</tbody>
</table>

1820 12,548 1.8 228,600 32.9 1,814.3
1870 98,374 8.9 189,740 17.2 192.9
1913 517,383 19.1 241,344 8.9 46.6
1950 1,132,434 21.2 239,903 4.5 21.2
1973 3,536,622 22.0 740,048 4.6 20.9
1998 7,394,598 21.9 3,873,352 11.5 52.4

NOTE: Figures in millions of 1990 dollars

Table 2
Projected U.S. and Chinese GDP Growth\textsuperscript{30}

<table>
<thead>
<tr>
<th>Chinese GDP as % of U.S.</th>
<th>Chinese GDP</th>
<th>U.S. GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>U.S.</td>
<td></td>
</tr>
</tbody>
</table>

2005 8,359 12,487 66.9
2010 13,882 16,041 86.5
2015 22,210 20,169 110.1
2020 35,734 27,584 129.5
2025 57,145 35,963 158.9

NOTE: Figures in billions, adjusted by purchasing power parity

Another measure of power is, self-evidently, military expenditures. We see a picture of rising Chinese military expenditures (see Figure 1), but U.S. spending still dominates the comparison. China’s official 2008 budget is $59 billion vs. $481.4 billion for the U.S. defense budget. This is roughly an eight-fold difference. However, perhaps this difference is not as great as it seems.


Chinese official budgets probably understate their actual expenditures. RAND has proffered several necessary adjustments to compare China’s expenditures to U.S. expenditures. PPP manifests itself in lower pay for People’s Liberation Army (PLA) personnel and lower wages at defense factories. This deflates costs and raises China’s “true” or “comparable” defense budget. Less dramatically, Chinese provinces also contribute to defense goals, and their spending must be taken into account. Lastly, the state subsidizes many state-owned enterprises that supply and contract to the PLA. These adjustments mean that the nominal $22 billion 2003 PLA budget is better expressed as $68.6 billion of military spending (RAND’s mid-range estimate). DoD employed similar adjustments to arrive at its estimate of Chinese

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32 Crane et al., Modernizing China’s Military: Opportunities and Constraints, pp. 125-134.
33 Crane et al., Modernizing China’s Military: Opportunities and Constraints, p. 233.
military spending for 2007, somewhere between $97 billion and $139 billion.\textsuperscript{34}

In addition, U.S. defense expenditures are spread out among diverse commitments around the world - the necessary role of the hegemon. In contradistinction, the PLA is able to concentrate its expenditures on building capabilities in a relatively small region of the world. On a regional basis, its expenditures may already be sufficient to support Chinese freedom of action in the western Pacific and challenge the United States at least for regional primacy.

Thus we see that the rising cost to the United States of maintaining its global hegemony have made room for a challenger state to emerge. China, with a quickly growing economic base and defense budgets to match, could overtake the United States in terms of power in the foreseeable future. This pattern of differential power growth seems to fit the conditions for hegemonic war described by Gilpin.\textsuperscript{35}

**Considering the Current International Order and Peaceful Hegemonic Transition**

Gilpin presents a macro-view where the changing relative power between hegemon (United States) and rising power (China) compels the rising power to fight the hegemon for control of the international system. The challenger’s goal is to change the old order, sponsored by the old hegemon, in the rising state’s favor. But G. John Ikenberry claims that “The rise of China does not have to trigger a wrenching hegemonic transition.”\textsuperscript{36}

We have certainly seen hegemonic change repeatedly throughout history, as a rising power fights to change the old international order. But the current order already is in China’s favor. Indeed - openness,


\textsuperscript{35} In fact, one measure of national power - the Comprehensive Index of National Capacity (CINC) in the Correlates of War (COW) database, currently assesses the U.S. and China at near parity. We will revisit this later in the empirical section.

trade, and liberal international relations where the international system is governed largely by consent, and the free flow of capital – characteristics of the international order invented by the U.K. and subsequently expanded by the United States – created the conditions for China’s rise from abject poverty. The current order is “open, integrated, and rule-based, with wide and deep political foundations” – fundamentally different from orders challengers faced in the past.37

Gilpin did not necessarily treat the case where the old order created the rise of the new challenger – so we are left in a bit of a theoretical grey area. But is this a tautology? Would the old order have, by definition, allowed the rise of a new challenger, and thus already been subsumed by Gilpin’s argument? Perhaps not: Gilpin’s examples – Sparta, the Goths, etc. – all rose independent of or in spite of the system the old hegemon promoted, not as a direct result of that system.38

Ikenberry points to the current system and claims that a rising China has no reason to overturn it (provided the West follows his recommendations).39 Indeed, the current international system benefits China enormously. Ikenberry essentially makes a “this time it’s different argument:” as long as the United States and the West adapt to changing realities by strengthening the collective, collaborative elements of the international system and downplaying the West-dominated elements. This entails bringing in new states into leadership organizations and institutions (currently dominated by the great powers of yesterday).40 Kishore Mahbubani supports similar policies, arguing that the West must cede a share of its stakes in organizations like the IMF and World Bank.41

38 Gilpin, War and Change in World Politics, pp. 96, 189.
But that China is currently benefited by the current order does not necessarily mean that there are not some “tweaks” – ways it could take the current order and fine-tune it in their interest. In other words, benefiting from the current order does not preclude the existence of a different set of even more beneficial rules governing the international system. We could probably think of several perennial concerns of China that it could solve with system tweaks – for example, the de facto prohibition of the use of force or tough diplomacy against Taiwan, and the incessant embarrassment over human rights abuses (that the Chinese feel are necessary to maintain order, unity, and the public good).

Ikenberry claims that these tweaks are not important enough to risk wrecking the current order. He argues, rather compellingly, that stability will prevail if and only if the United States and the West begin to include a greater role for China (and other rising powers, notably India and Brazil) in international institutions.42

While Ikenberry’s arguments are compelling, the necessary abstraction to organize the actors and motivations is at the state level, and we know that there are many countervailing forces at work within a state. History has taught us that these forces may come together in unanticipated, if not chaotic ways. Results may be rather different from a rational decision calculus. This is essentially an application of Ken Arrow’s impossibility theorem.43 Thus, even if the current order is advantageous to China, and even if it is likely that the tweaks are not worth risking wrecking the current system – latching on to one issue (e.g., Taiwan) may drive a state in a different direction, despite its actual interests. There is a risk that the Communist Party could lose control of nationalism.44

So assume Ikenberry is correct – that China’s rise can be accommodated with a wise policy of engagement from the West. Certainly

his recommendations do seem like wise policy for grooming a state to assume a responsible position, co-leadership or perhaps even leadership, in the international system. But will these policies be enough? Although Ikenberry’s scenario may be most likely, we cannot be entirely certain. A strategy of pure engagement will not be robust to the prospect, even if unlikely, of deteriorating relations. A two-pronged policy may be more effective to encourage peace and collaboration, while simultaneously deterring undesirable behavior.

AN INTRODUCTION TO THE EMPIRICAL PERSPECTIVE: STRUCTURAL FACTORS OF WAR

Geller and Singer, in their meta-analysis, “Nations at War,” synthesize the conclusions of a variety of empirical investigations of factors correlated to war. Notably, many of these studies have used the Correlates of War (COW) database, which has a host of information from 1816 to the present on countries, their relationships, and the wars in which they engage. The database defines a war as a conflict between states involving at least 1,000 battle deaths.45 A typical empirical investigation of war-proneness will employ regression methods to test the relationship between a dependant variable (like number of years over the sample frame in which two countries were at war) to an independent variable (say, pre-war balance of power between the countries) while controlling for other factors. Geller and Singer examine empirical studies at four distinct levels of investigation: the state level, the dyad level, the regional level, and the international system level. For their relevance to the U.S.-China relationship and the likelihood of armed conflict between the two, we will focus on state-level and dyad-level factors.

The state level encompasses factors linked to a single state’s propensity for war. Empirical studies have found that war is correlated with a critical point in the state’s power cycle (e.g. transition from second-rate to major power). Interestingly, factors that we would think a priori to be important predictors of war-proneness - democracy,

alliances, and great power status—seem to be unreliable predictors of a single state’s war-proneness.46

But although a single state may be more or less prone to war, wars are by definition between states. In order to develop a full and rich empirical picture of war-proneness, it is necessary to examine factors between states, or elements in the states’ relationship. Geller and Singer refer to this as dyad-level analysis. Much of the empirical work has tested earlier theoretical work—for example, we see Gilpin’s historical change process put to the test. Many of the criteria empirically tested will be familiar to any student of international relations as predictions of realpolitik, though Geller and Singer show that the predictions of realpolitik manifest themselves in unexpected ways.47 For example, balanced capabilities actually make states more war-prone, which conflicts with the classical realist argument that alliances form to balance power for security and peace.48 Empirical examinations of dyad-level factors have revealed that the following factors that are predictive of war-proneness of a dyad:49

- A rough balance in capabilities exists between two states.
- There is a shift or transition in relative power between states (especially a shift to parity).
- States are in close proximity or are congruent (share a border).
- The states have an outstanding territorial dispute (which compounds in magnitude if the states are contiguous).
- An arms race is underway.

There is a large difference in development between the states.

An enduring rivalry exists between countries.

Certain factors reduce the war-proneness of a dyad, most notably a strong trading relationship. Also, Geller and Singer claim that there is support for democratic peace theory, the idea that two democracies are unlikely to wage war against each other. Mansfield and Snyder present strong evidence that new democracies are actually more likely to go to war. The most recent scholarship does not investigate who new democracies tend to war against, but in light of these somewhat conflicting trends, we will combine the criteria as such: mature democracies are less likely to go to war against each other (a dyad-level factor), whereas democratizing nations are themselves more war-prone (a state-level factor).

Applying Empirical Explanations to the U.S.-China Dyad

Now let us examine the U.S.-China relationship using the insights we have gleaned from the overview of empirical predictors of war.

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52 Mansfield and Snyder postulate several reasons why this phenomenon occurs. The new government often has not yet developed a system to mollify mass-oriented politics. Newly democratic governments are full of unseasoned actors who have not yet learned to carefully navigate diplomacy. And, most worryingly for a possibly democratizing China, once out of domestic scapegoats, the newly formed government must turn public revolutionary fervor outward to maintain unity. The new French republic in the years immediately following the French Revolution was a perfect example. See Edward Mansfield and Jack Snyder, "Democratization and the Danger of War," in National Security, Summer 1995.
53 Even this claim is somewhat tenuous, for most of the time span of the data, there were only a handful of democracies in the international system, not really enough data from which to draw strong conclusions.
54 Mansfield and Snyder, "Democratization and the Danger of War," p. 12.
55 Also, it is important that the factors have only been examined in isolation. In other words, their effects are not necessarily (Continued on the next page).
Rough Capability Balance. Contrary to the expectation of classical realpolitik, a capability balance tends to make war within a dyad more likely.\textsuperscript{56} This actually is congruent with Offensive Realism, which postulates that states do not seek a balance, but seek hegemony as the ultimate guarantee of security.\textsuperscript{57} This finding is also congruent with a game-theoretic perspective: a rough capability balance maximizes the chances that either or both states will misjudge their chances of victory - hence making conflict initiation more likely (the converse being that a state should be under no illusions about its prospects for victory if it were to initiate a war with a much stronger state).

We have seen that China and the United States may soon have roughly the same economic output. Of course, GDP does not necessarily equate to capability. In the COW database on which these empirical studies are based, capability is measured by the Comprehensive Index of National Capability (CINC), an index which includes a state's iron and steel production, military expenditures, military personnel, energy usage, and total population.\textsuperscript{58} These measures are aggregated and expressed as a proportion of total world capability (i.e. the current U.S. score of about .15 means the United States possesses roughly 15% of total world capacity). As to whether this measure is valid: while not a perfect measure of capability, this index captures many elements of power. It is also consistent with widely recognized patterns of hegemony: Britain, as world hegemon for much of the 19\textsuperscript{th} century, had the additive. Thus, we cannot use them to estimate a probability of war between the U.S. and China; we can only point to factors that make war more or less likely.


\textsuperscript{57} See Mearsheimer, "Anarchy and the Struggle for Power," pp. 50-60.

\textsuperscript{58} The explanation is available in "Correlates of War Project National Material Capabilities Data Documentation," Version 3.0, May 2005. Available at <http://www.correlatesofwar.org/COW2\%20Data/Capabilities/nmc3-02.htm>. The database administrators experimented with adding more modern measures of power (e.g. semiconductor production). Finding little difference in the data, they chose to continue using the original measures for ease of comparison across years.
highest CINC for those years – hovering at about 30% of world capacity for most of the first half of the century. As historians would observe, it declined prior to WWI when other European powers, notably Germany, began to catch up. U.S. CINC was the highest after World War II, but at the height of the cold war had narrowed to .21 vs. .18 for the Soviet Union.\(^{59}\)

The most recent CINC measures put the United States and China at .149 and .137 respectively, closer to parity than the United States and Soviet Union ever were. While the CINC scores do not measure the technological quality of a state’s military, we would imagine that eventually China’s GDP growth and population could translate into technological parity or near-parity. Further, while the U.S. military in general may be judged to be vastly superior to China’s, the particular geography of the western Pacific neutralizes some of U.S. technological advantages – which chapter 3 will explore in detail.\(^{60}\)

For example, the geography of the region does not permit the U.S. Air Force to operate as it has in the recent past. The stunning airpower victory in the 1991 Gulf War, for example, was made possible by operating large numbers of aircraft from many bases very close to the enemy.\(^{61}\) However, the sparse operating locations in the vast Pacific Ocean (not to mention China’s ballistic missile arsenal) however, would make this mode of operations impossible in a war with China. Thus, many American technological advantages are not as relevant in a war with China. We will discuss this particular point in more detail in the following chapters.

**Shifts in Relative Power.** Geller and Singer’s meta-analysis confirms that a shift in relative capabilities between dyad members makes that dyad more prone to war. Again, this finding is consistent with the hegemonic change perspective we have previously examined. We

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\(^{59}\) Correlates of War Database.


have also noted that China and the United States have a rough balance in capabilities, as measured by the COW database. We are also aware of the differential growth rate and China’s unprecedented transition from poverty to world power. Suffice it to say there has been a significant shift in relative power between the United States and China. Figure 2 depicts convergence of one measure of U.S. and Chinese power in the period 1991-2001. The figure uses the CINC data discussed previously. While the U.S. CINC is relatively unchanged over this period, we see China’s capability steadily rising.

**Figure 2**


Critical Point in Power Cycle. This empirical finding is a confirmation of Gilpin’s “war as a process” theory. In the treatment of this theory as it relates to China and the United States, we have previously examined whether China is at a critical point in its power

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62 Correlates of War Database.
cycle. Because of rapidly rising economic output (which may eventually overtake the United States’ output), defense budget growth, and approaching regional military parity with the United States, we can conclude that China is transitioning to a new level of power – making it, as a state, more war-prone.63

**Proximity.** Proximity is correlated with war-proneness, but China and the United States are not neighbors, nor are they particularly close. The closest U.S. possession, Guam, is 1,600 nautical miles from the Chinese coast. This does not make the United States and China any more or less war-prone.

**Arms Races.** Geller and Singer put forth two criteria for an arms race to exist: concurrently rising defense expenditures and an ongoing rivalry.64 That is, the rising defense expenditures must be in competition. We do not observe these patterns in the U.S.-China relationship, and Geller and Singer find that arms races are inconclusive.

**Democratization.** There has been much speculation on if and when China may begin to democratize.65 While one might think that democratic developments and individual rights proceed hand-in-hand with economic development, so far the Communist party has managed to maintain, if not strengthen, its control. Democratic movements – like Tiananmen in 1989 – have been repressed. This experience is not inconsistent with an East Asian model of authoritarian, market-oriented government which eventually transitions to a democracy (as did the ROK and Taiwan). If China begins to move towards a democratic system, it may actually be more prone to go to war during the transition to a mature democracy.

**Development Difference.** The empirical work reviewed by Geller and Singer has found that a large difference in development makes a dyad

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63 See previous discussion on pp. 8-16.
64 Geller and Singer, **Nations at War: A Scientific Study of International Conflict**, p. 79.
more war-prone. The most convenient measure of development, GDP per capita (adjusted by PPP), shows a roughly 85% development gap in 2005. Although it is slowly diminishing, and at some point in the distant future may not be too pronounced, the development difference is still huge and will be for some time.\textsuperscript{66} For the time being, and for the foreseeable future, the large development difference between the United States and China may increase the likelihood of conflict.

**Mutual Trade.** Mutual trade has been shown to decrease the war-proneness of a dyad. U.S.-China trade is booming and growing (see Table 3). The world as a whole is interconnected as never before, as are the U.S. and Chinese economies in particular. Thus we would expect the trade effect, empirically shown to be significant in the years 1870-1938\textsuperscript{67} to be perhaps even stronger in today’s global marketplace. Charles Wolf has noted that one key area of hope for peaceful relations is that the imbalances in each country’s economy are complementary.\textsuperscript{68} On the other hand, while a war would certainly have devastating effects on the economies of both countries, this tends to be a feature of great power war in general, and the world has seen many examples of countries warring when it made no economic sense. Observing the strong interdependence of the U.S. and Chinese economies should not be mistaken for dismissing the prospects for violent conflict, but interdependence certainly offers both nations strong incentives to overcome differences peaceably.

\textsuperscript{67} Geller and Singer, Nations at War: A Scientific Study of International Conflict, pp. 93-94.
Table 3
Nominal U.S.-China Trade, 1980-2005\textsuperscript{69}

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. Exports to China $Billion</th>
<th>U.S. Import From China $Billion</th>
<th>U.S. Trade Balance $Billion</th>
<th>%GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>3.8</td>
<td>1.1</td>
<td>2.7</td>
<td>0.10%</td>
</tr>
<tr>
<td>1985</td>
<td>3.9</td>
<td>3.9</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>1990</td>
<td>4.8</td>
<td>15.2</td>
<td>-10.4</td>
<td>0.18%</td>
</tr>
<tr>
<td>1995</td>
<td>11.7</td>
<td>45.6</td>
<td>-33.8</td>
<td>0.46%</td>
</tr>
<tr>
<td>2000</td>
<td>16.3</td>
<td>100.1</td>
<td>-83.8</td>
<td>0.85%</td>
</tr>
<tr>
<td>2005</td>
<td>41.8</td>
<td>243.5</td>
<td>-201.6</td>
<td>1.62%</td>
</tr>
</tbody>
</table>

**Mature Democracies.** There is a fair body of empirical evidence supporting the widely-held belief that mature democracies do not go to war against each other (note that this concept is different from an emerging, or new democracy, discussed previously). There is also a great deal of controversy. There is no need to settle that debate here, as only the United States can be considered a mature democracy.

**Great Power Status.** Geller and Singer find that the empirical work they reviewed regarding great power status is conflicting, and we cannot draw conclusions from it. Great power status is a state-level attribute. We may hypothesize that great powers tend to have different national interests and be more inclined to attempt to change the system to their favor. In contrast, second-rank powers may have a different perception of what constitutes their interest, and may be more inclined to take the external world as it is presented to them (i.e. are less inclined to coerce the behavior of other states). Both China and the United States, by measure of land area, population, GDP, or military expenditures, are great powers. Since study results on the effect of great power status are mixed, we cannot infer war-proneness.

**Nuclear States.** Somewhat surprisingly, empirical work has failed to show that nuclear powers are any less war prone as states, or as dyads (where both are nuclear armed). This may be attributable to the

small case size – nuclear weapons have only existed a short time, and the number of states that possess them are small. China has a medium-tier nuclear arsenal, focusing on minimal strategic deterrence. Its 2nd Artillery Corps possesses perhaps 50 ICBMs and up to 350 warheads. The United States has a very advanced deterrent arsenal. However, these attributes are not empirically significant.

Summarizing Structural Factors in the U.S.-China Dyad. Table 4 summarizes the presence or absence of factors influencing the war-proneness of states and dyads. We can see that many of the factors predictive of war are present in the U.S.-China relationship. A rough capability balance, a shift in relative power between the United States and China (in China’s favor), and a development difference all are correlates of a war-prone relationship. If China were to begin down a path of democratization, the picture would become more worrying. However, there are also hopeful signs: mutual trade is high and rising, and many of the predictors of war-proneness are not present in the U.S.-China relationship. At least one predictor, the difference in development, is rapidly diminishing (although still very large).

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### Table 4
Empirical Attributes of War-Prone Dyads Applied to the U.S.-China Dyad

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Level</th>
<th>Direction</th>
<th>Presence</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rough capability balance</td>
<td>Dyad</td>
<td>↑</td>
<td>✓</td>
<td>Defense expenditures, CINC, qualitative analysis</td>
</tr>
<tr>
<td>Shift in relative power</td>
<td>Dyad</td>
<td>↑</td>
<td>✓</td>
<td>Defense expenditures growth differential</td>
</tr>
<tr>
<td>At critical point</td>
<td>State</td>
<td>↑</td>
<td>✓</td>
<td>GDP growth, defense expenditure growth</td>
</tr>
<tr>
<td>Proximity</td>
<td>Dyad</td>
<td>↑</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Arms race</td>
<td>Dyad</td>
<td>—</td>
<td>—</td>
<td>Concurrently rising defense expenditures</td>
</tr>
<tr>
<td>Democratizing</td>
<td>State</td>
<td>↑</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Development difference</td>
<td>Dyad</td>
<td>↑</td>
<td>✓</td>
<td>GDP per capita difference, HDI difference</td>
</tr>
<tr>
<td>Mutual trade is high</td>
<td>Dyad</td>
<td>↓</td>
<td>✓</td>
<td>Magnitude</td>
</tr>
<tr>
<td>Mature democracies</td>
<td>Dyad</td>
<td>↓</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Great power</td>
<td>State</td>
<td>—</td>
<td>✓</td>
<td>UN Security Council, GDP rank, defense expenditure rank</td>
</tr>
<tr>
<td>Nuclear-armed</td>
<td>Dyad</td>
<td>—</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Up/down arrows indicate more or less war-prone. Check marks indicate presence of attribute.
Note that there is a high degree of correlation between the empirical factors related to war-proneness and the explanation of hegemonic change proffered by Gilpin. We have seen that both perspectives yield a considerable body of evidence which suggests that war between China and the United States a possibility. Yet there are also tentative signs that the situation may not be so dire – including the current world order’s peaceful bias and the economic interests at stake. The structural evidence is definitely mixed.

THE TAIWAN STANDOFF

So far, structural perspectives have shed some light into the structural factors that predispose countries to war. We have also examined to what extent the empirically-tested structural precursors of war are present in the U.S.-China relationship. But conflicts have structural causes and more immediate, proximate causes. History has seen structural tensions manifest themselves in conflict through seemingly random chains of events. For example, the dawn of the First World War saw two armed camps which possessed many of the structural precursors to war. But it took an assassination in an obscure corner of Europe, followed by an unlikely chain of failed crisis management, to transform the tension into widespread armed conflict. It is also likely that there are wars that “should” have occurred but were averted by successful crisis management. This must be the case, because obviously none of the empirically-shown structural precursors are completely reliable predictors of war.

It is unlikely that either the U.S. or China would at any point prefer conflict to peace, but in some specific scenarios the gamble of escalation could be preferable to a highly unfavorable peace. Thomas Christensen lays out several cases in which China, even if it believes itself militarily weaker in a broad sense, may choose to use military force against the U.S.

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Chinese leaders may choose to escalate if they believe they are “backed into a corner” and refraining from the use of force would be prohibitively costly to the regime. In this scenario, Chinese leaders, though uncertain of the military outcome, presume that the domestic outcome of restraint would likely be regime change. This could convince them that escalation might be the only acceptable course of action.72

Chinese leaders may escalate if they believe they can effectively deter U.S. intervention by threatening casualties and a costly war. This condition would be based on the perception that the U.S. lacks resolve, or that the U.S. does not believe its interest in the region is great enough to sacrifice American lives and wealth.73

China may be more willing to use force if the U.S. military is distracted elsewhere. Christensen observes that the post-Cold War drawdown made it unlikely that the U.S. military could actually fulfill its stated objective to fight two major regional conflicts at once.74 This trend has only become worse with the military’s current focus on irregular wars.

Lastly, China may use force if it believes the U.S. can be separated from regional allies through military coercion or diplomacy.75 This will be a major discussion theme in chapter 4.

What crises could precipitate U.S.-China conflict? We now consider what, specifically, could cause U.S.-China conflict. We will see that most of the possibilities that receive serious attention—competition over oil, economic or trade disputes, a conflict over ideology, or a Chinese attack on a country whose security the United States guarantees

are very unlikely. However, the Taiwan problem has some unique properties that could very well devolve into conflict — even if conflict is not sought out by any of the parties.

Many of these theoretical flashpoints have little substance. Consider oil competition or competition for natural resources more generally. The United States is the world’s biggest consumer of oil, followed by China. China’s oil consumption is growing rapidly — it increased by 90% from 1993-2002 and is expected to continue growing.76 Extrapolating these trends, and given that there is a finite amount of oil, so the argument goes, either the United States or China will need a portion of the other’s oil and consequently come to blows. However, China and the United States actually share interests when it comes to oil and natural resources in general. China benefits considerably from U.S. sponsorship of the global trade regime — which allows all countries of the world relatively free access to natural resources via global markets. A Chinese resource grab could actually degrade China’s access to resources by disrupting U.S. sponsorship of the international trade regime. Further, as Bush and O’Hanlon note, the U.S. and Chinese economies are interconnected — if either had an oil shortage the other would experience serious detrimental effects.77

Bush and O’Hanlon also note several economic trends that could be concerning: a trade imbalance, the intentionally depressed Yuan, a failure to protect intellectual property, and China’s industrial espionage and technology theft. While these issues are concerning, none might feasibly plunge the U.S.-China relationship into conflict. In fact, the existence of these issues is a testament to how interdependent the U.S. and Chinese economies are. The United States runs a significant trade deficit with China, due to high levels of consumption. China finances this consumption by buying unprecedented amounts of U.S.

debt and depressing its currency, rather complementary imbalances, to paraphrase Charles Wolf. And while technology theft and a lack of respect for intellectual property are concerning, these problems are diminishing as China learns how to be a responsible member of the international trade regime and begins to have a stake in protecting its own technology and intellectual property rights. Mutual economic interest should lessen economic tensions over time. The “likely scenario is for the two sides to muddle through and find ways to manage the economic tensions rather than be trapped by them.”

The United States could hypothetically become involved in a conflict between China and a regional U.S. ally. Gilpin highlighted a Great Power’s entanglement with a smaller power as historically one of the major destabilizing factors in the international order:

It was the ambitions of Sparta’s ally, Corinth, and its provocations of Athens that precipitated the great war between the Peloponnesian and Delian Leagues. The difficulties of Germany’s ally, Austria, beset with a decaying multiethnic empire, escalated into World War I. In neither of these cases could the major power tolerate the defeat or the disintegration of its minor ally.

While Gilpin makes the case that this dynamic is less likely in today, the prevalence of historical wars attributed to such entanglements means that we must fully examine this possibility in the U.S.-China relationship.

China has a number of outstanding quarrels with its neighbors, some of whom have close relationships with the United States. Take the example of the South China Sea. China claims the entirety of the Spratly and Paracel island groups, and more importantly, the seabed resources of the South China Sea. These claims conflict with the

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80 Bush and O’Hanlon, *A War Like No Other: the Truth About China’s Challenge to America*, pp. 49.
81 Gilpin, *War and Change in World Politics*, p. 236.
Philippines, Malaysian, Bruneian, Vietnamese, and Taiwanese claims. However, the magnitude of these conflicts are very small in comparison to the mutual interests of these countries, and China has shown willingness to resolve such issues multilaterally.

There are clearly unresolved issues in the China-Japan relationship: continued animosity over Japanese behavior in WWII, Japanese leaders’ visits to war shrines honoring war criminals, and the islands and seabed resources whose ownership the two countries dispute. However, despite these difficulties, "the two countries are quite pragmatic." While China may stoke nationalist sentiment and encourage protests against Japan, it usually calms those protests just as quickly. Anti-Japanese sentiment is a double-edged sword from the perspective of the Chinese government – protests against Japan could quickly develop into general unrest and protests against the PRC government itself. Japanese attempts to ignore the country’s history are generally overblown. Further, as we have seen before, U.S. power in the region is stabilizing: it protects Japan from China while keeping Japan disarmed by providing it security guarantees. Thus the possibility of the United States and China going to war over a crisis involving a U.S. ally seems remote, except for perhaps one: Taiwan. The outstanding issues between the PRC and Taiwan are less easily resolved, are core to each entity’s identity, and could lead to conflict if not managed carefully. We now turn to a discussion of those issues.

The Importance of the Taiwan Issue

While certainly not the only possible catalyst, Taiwan stands out as the most likely catalyst for U.S.-China conflict. Why? There are

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83 Bush and O’Hanlon, A War Like No Other: the Truth About China’s Challenge to America, pp. 45.
84 Bush and O’Hanlon, A War Like No Other: the Truth About China’s Challenge to America, p. 46.
85 Ibid.
encouraging signs such as cross-strait investment and dialog; but many concerning factors exist: Chinese military modernization seems intended for a Taiwan conflict; the Taiwan standoff is consistent with many of the empirical explanations for conflict; recovering “lost territories” is central to Communist Party legitimacy; cross-strait views of how reunification should proceed are incompatible; and well-functioning communications channels, which would normally help ameliorate crises, are nonexistent.

We may look to Chinese military trends that reveal China’s perception of cross-strait relations. Chinese military modernization is focused on a conflict over Taiwan. The direction of PLA efforts provides clues: “Since the end of the 1990s, PLA reform, modernization, procurement, and training have been heavily – almost singularly – focused on preparing for a conflict over Taiwan.”87 A read of PLA modernization doctrine will reveal recurring themes: preparing for “high-tech regional wars,”88 and preparing to “defeat the superior with the inferior.”89 A high-tech war under modern conditions refers to Chinese planning for a violent, quick conflict where information and escalation dominance play a large part. A conquest of, or armed diplomacy against, Taiwan would certainly be a limited, regional war (as opposed to the massive people’s land wars against an enemy like the Soviet Union for which the PLA was optimized for decades). And defeating the superior with the inferior can really have only one meaning, since China faces only one superior military power, the United States. The confluence (or triangulation) of these themes points clearly to preparations for the possibility of some kind of violent...

87 Crane et al., Modernizing China’s Military: Opportunities and Constraints, p. 194.
action against Taiwan, in which China may need to face and defeat U.S.
military power.

That the PLA is preparing for a war over Taiwan is one reason to
take the Taiwan situation seriously. Another reason is that conflict
over Taiwan is congruent with many of the factors empirically shown to
make war more likely. At the state-level, we have seen that China is at
a critical point in the power cycle. Also, if China begins
democratizing, that would also constitute another structural precursor
to conflict. At the dyad-level, Taiwan and China are proximate (or
contiguous across a 100-mile strait). Secondly, there is an outstanding
territorial dispute between the two powers – the entire ROC itself (the
ROC used to claim to be the legitimate representative of all of the
PRC’s territory as well, in which case each state had a territorial
claim to the entirety of the other state). This outstanding territorial
dispute combined with the long militarization of the Straits constitutes
an enduring rivalry, raising the risks of war.90

The reunification of Taiwan with the mainland is a key national
goal for China: "The struggle to oppose and contain the separatist
forces for ‘Taiwan independence’ and their activities remains a hard
one... posing a grave threat to China’s sovereignty and territorial
integrity, as well as to peace and stability across the Taiwan Straits
and in the Asia-Pacific region as a whole."91 Now that the mainland
government no longer relies on communist ideology as a source of
legitimacy, it tends to emphasize two other sources: delivering
continued economic growth, and reversing China’s "century of
humiliation:" restoring China to its former territorial integrity and
central position in Asia. Taiwan is perhaps the only outstanding
territory yet to be retaken by China, and as such is a key piece of the
PRC’s claims to legitimacy.

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90 Geller and Singer, Nations at War: A Scientific Study of
International Conflict, p. 150.
91 Information Office of the State Council of the People’s Republic
of China, 2006 China National Defense White Paper, Beijing, 2006, p. 6,
However, despite the centrality of Taiwan to Chinese policy, it seems that China recognizes that recklessly pursuing Taiwan would be counterproductive. Reckless action would increase the likelihood that Taiwan would move towards real independence and increase the likelihood that the world would recognize that independence. A war would also severely derail China’s economic growth, and risk losing that source of legitimacy. For these reasons the PRC seems content to continue with the status quo, although it would clearly feel the need to respond if it felt that Taiwan was moving irreversibly away from the mainland. The Taiwanese public, for its part, also seems content with the status quo as well. Recent opinion polls show that 80% percent favors the status quo, 8.5% percent immediate independence, and only 3.1% percent immediate reunification.92

There are other encouraging, friendly signs in cross strait relations. Taiwan is the mainland’s biggest source of investment and a key trading partner. Taiwanese businessmen were integral in facilitating Deng Xiaoping’s economic reforms in the 1980s. Today Taiwan and China are bound together economically like never before, indeed much more so than when Taiwan was still a de facto piece of China. With the growth of economic relations came a general political warming as well: relations are much more cordial today than in the past. In the last 30 years, the relationship has progressed from the intermittent shelling of Quemoy and Matsu to cross-strait passenger flights and open dialog on a variety of issues. The contentious leadership of pro-independence president Chen Shui-bian, who antagonized China repeatedly, is also at an end, and there appear to be signs that the relationship will be less contentious with Ma Ying-jeou at the helm.

Despite these encouraging signs, there are still serious hang-ups. Today, neither side is opposed, per se, to a dialogue on the future of Taiwan’s status. Nor is Taiwan fundamentally opposed to some form of reunification with the mainland. However, each side has their own

92 Ching-hsin Yu, “Taiwan’s Electoral Politics 2008,” Election Study Center at National Chengchi University, Taiwan.
(mutually exclusive) ideas of what this may look like. China insists on Taiwan committing to the “one China principle” before entering into any negotiations. Taiwan refuses, because such a commitment to China’s version of one-China would color the rest of the negotiations and cede de facto and theoretical sovereignty to China before negotiations even begin. China’s concept of “One China, Two Systems” (as previously applied to Hong Kong and Macao) is really total Chinese sovereignty, with some delegation of local policymaking to local authorities. This kind of unification is unacceptable to Taiwan, which at a minimum would require reunification to be something more of a combination of equals. For the moment, this impasse precludes further discussion.

Despite this impasse, it seems for now that both China and Taiwan realize that they have more to gain by cooperation than confrontation. However, bumps in this relationship will occur. Managing their differences requires open communication and a willingness to engage. Unfortunately, these attributes are largely absent in the relationship. China and Taiwan have limited formal communications channels, and thus no formal mechanism to resolve crises. This means that there is the very real and ongoing potential that a small problem could quickly become a big problem. In crises of the past, both governments have tended to use the United States as an intermediary, but this method is far from perfect. First, the United States is not up to the role of impartial mediator—it too has much at stake in any Taiwan-China crisis. Second, the United States has only limited sway with either side. Third, the PRC government tends to close itself off in the midst of crises. The communication problems are very worrisome, and hold the greatest potential that the PRC and Taiwan will be in conflict with each other.93

Bad decisions may result from bad information, miscalculation of costs and benefits, a mis-estimation of the likelihood of success, or just plain old irrationality. Unfortunately, there are many

93 Bush and O’Hanlon, A War Like No Other: the Truth About China’s Challenge to America, pp. 84-86.
opportunities for misperceptions to complicate the decision chain in a Taiwan crisis. The inherent U.S. participation in any cross-strait dialog is both calming and concerning. It is calming because the United States can act as an unofficial communication channel between two parties who tend to communicate poorly, if at all. It is concerning because the existence of a crisis triangle compounds the opportunities for bad information – now each actor must not only understand his own capabilities and likely reactions, he must know the capabilities and reactions of two other actors, and must know that they know the capabilities and reactions of the other two actors, and so forth.

Beyond the simple volume of information that each actor needs to process, we can identify some characteristics of the Taiwan situation that make perfect information hard to obtain. Some potential areas of misunderstanding include:

- Taiwan may overestimate the probability that the United States will intervene in a crisis, skewing their decision calculus towards crossing a Chinese “red line,” assuming China will be deterred by the prospect of U.S. intervention.
- China may not understand U.S. commitment or the conditions under which the United States will intervene. An estimate of Taiwan’s will to fight is also critical to China’s decision calculus.
- The United States may underestimate PLA capabilities or Taiwan’s will to fight.95

94 Discussion of what constitutes a “red line” proceeds in more depth on p. 45.
95 Corroborating this analysis, OSD states that, “As PLA modernization progresses, three misperceptions could lead to miscalculation or crisis. First, other countries could underestimate the extent to which PLA forces have improved. Second, China’s leaders could overestimate the proficiency of their forces by assuming new systems are fully operational, adeptly operated, adequately maintained, and well integrated with existing or other new capabilities. Third, China’s leaders may underestimate the effects of their decisions on the security perceptions and responses of other regional actors.” OSD, Military Power of the People’s Republic of China 2008, p. 32.
Decreased ambiguity would aid the decisionmaking of all parties. U.S. policy should encourage cross-strait dialog, including establishing permanent communications channels. Any intentional ambiguity in policy necessarily raises the risks involved in a crisis management chain. Most notably, the intentional American strategic ambiguity regarding its commitment to Taiwan carries with it serious risks should the Taiwan situation devolve into crisis. The U.S. position is intentionally ambiguous — intending to deter China from aggressive action while avoiding giving Taiwan free reign to declare independence. It thus serves a useful diplomatic purpose, carefully balancing competing commitments. However, the United States must be prepared to clarify its strategic ambiguity quickly should an emergency arise. Failure to do so would obfuscate the decisionmaking of China and Taiwan, and increase the risk of an unintentional war which the United States may be compelled to enter. Other measures may further increase information available to other actors — for example through increased military-military contacts, open communication channels, etc.

U.S. policymakers must be realistic about PLA capabilities, and the prospects for victory in a war over Taiwan. While it is evident that the United States possesses the most advanced military in the world, the PLA has advanced systems as well, many of which specifically exploit U.S. weaknesses. Given PLA strategic depth and the enormous access challenges the United States faces in the western Pacific, many typical U.S. advantages may be nullified. Further, pursuing a deterrent strategy like deploying large concentrations of aircraft to forward bases may actually have an effect the opposite of intended deterrence. A large concentration of USAF assets within easy range of PLA ballistic missiles may be too tempting a target to pass up. If Chinese decisionmakers feel the situation is deteriorating anyway, preemptive action may be their best option to achieving their goals. In this way, U.S. misunderstanding of PLA capabilities would be disastrous to crisis

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stability. This prospect should motivate U.S. policymakers to either take steps to address weaknesses, or change foreign policy to accomplish the feasible.

CONCLUSIONS

Thus far we have applied three different explanations of conflict generation to the U.S.-China situation. Changing relative power can create a situation where a rising state feels that it would be to its advantage to go to war with a declining hegemon, in order to change the international system in its favor. While a rising China seems to fit this situation, the uniqueness of today’s international system based on its openness and liberalism may mean that such a violent transition need not occur.

We have also looked at several factors that have been empirically shown to raise the war-proneness of a state or a system, many of which corroborate Gilpin’s hegemonic change process. While the large and growing magnitude of trade is hopeful, several other factors make the U.S.-China dyad risky: a shift in relative power, China’s shift in power, the rough balance in national capability, and the difference in development. The shrinking difference in development will ease the chances of war between the United States and China; but were China to begin moving toward democracy, it would make it more prone to war.

These broad structural factors showcase some general risks to the U.S.-China relationship - if these risks manifest themselves in conflict, the Taiwan standoff would be the most likely proximate cause. Many other potential sticking points in the U.S.-China relationship - energy competition, economic disputes, or a Chinese war with a U.S. ally (other than Taiwan) - are much less likely, and, in many cases, the actors are fully motivated and empowered to resolve differences. The Taiwan problem, on the other hand, features two armed camps with incompatible goals and difficulties communicating their intentions. The information problems and abundant opportunities for misperception make it relatively easy for a minor crisis to develop into a major, perhaps world-changing war.
Many of the structural factors shown to be indicative of a risky relationship are concerning. But they also highlight some measures that may help preserve a favorable peace. Trade and the liberal world order may contribute to benign relations. It would be wise to emphasize such factors by promoting trade and emphasizing the uniting characteristics of the current international system. However, this should not be taken for complacency regarding the prospects for violent conflict. It would be a mistake to completely ignore the troubling aspects of the U.S.-China relationship. Reducing U.S. vulnerabilities is a key piece of being vigilant. In a crisis, a strong U.S. military capability may also tip China’s cost-benefit calculation towards seeking a peaceful resolution. Vigilance also includes taking steps to strengthen crisis stability by reducing opportunities for miscalculation by China, Taiwan, and the United States. While ambiguity may have diplomatic benefits, it may be wise to backpedal from strategic ambiguity if ambiguity appears to be contributing to the likelihood of a conflict. Other actions that may improve information, and hence, crisis stability include stronger mil-mil relationships and encouraging open and well-developed communications channels between China, Taiwan, and the United States.

China’s rise creates opportunities for peace and risks of conflict. A multi-pronged strategy for dealing with China’s rise would leverage areas of hope for peaceful relations while hedging against the possibility of deterioration by reducing U.S. military weaknesses. The remainder of this dissertation focuses on a particularly problematic U.S. military vulnerability: the reliance on airbases within fighter range of the area of operations.
3. TAIWAN OPERATIONAL CONTEXT

INTRODUCTION

China has several strategic options to project force against Taiwan in pursuit of reunification, or to persuade Taiwan to retrograde on a provocative policy. If the United States chooses to intervene, U.S. airpower will need to counter elements of these options. Below we discuss the literature on PRC military options, the difficulties inherent in the full-scale amphibious assault, and why a blockade may be more favorable to PRC decisionmakers. The air portions of an invasion, blockade, or other coercive option are explored below. We finish with a description of postulated opening attacks on USAF facilities in the region.

PLA OPTIONS

PRC stated policy has been to initiate hostile action if any of a number of “red lines” are crossed, most notably if Taiwan formally declares independence. Whatever the proximate cause, the PRC would not enter into such actions lightly - the international political consequences and the cost to China’s economy would be serious. This fact necessarily limits the effectiveness of U.S. options - if China is

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97 See Section II of China’s National Defense in 2000: “The Chinese government will do its utmost to achieve peaceful reunification, and advocates settling differences through dialogues and negotiations on the basis of the one-China principle. However, if a grave turn of events occurs leading to the separation of Taiwan from China in any name, or if Taiwan is invaded and occupied by foreign countries, or if the Taiwan authorities refuse, sine die, the peaceful settlement of cross-Straits reunification through negotiations, then the Chinese government will have no choice but to adopt all drastic measures possible, including the use of force, to safeguard China’s sovereignty and territorial integrity, and achieve the great cause of reunification.” Information Office of the State Council of the People’s Republic of China, China’s National Defense in 2000, Beijing, 2000, accessible at <http://www.china.org.cn/e-white/2000/index.htm>. Or see Article 8 of Tenth National People’s Congress, Anti-Secession Law, 14 March 2005, available at <http://english.people.com.cn/200503/14/eng20050314_176746.html>.
willing to pay such high costs, there is likely little punishment left
that the United States can reasonably inflict that would be worse. As
Christensen puts it, “the perceived balance of interests may be much
more important than the balance of power.”

China has a range of force options if it deems that the cross-
strait situation is threatening its vital interests enough to initiate
some kind of hostile action. Although these options are described below
as discrete choices, any actual course of action would likely be a
fluid, blend of military and diplomatic efforts. The history of Chinese
military conflict is replete with examples of very fluid transitions
across the spectrum of diplomatic efforts and military coercion to
achieve political ends. China’s strategy would be flexible and may
include violent escalation if it senses that diplomacy is not proceeding
favorably, rapid de-escalation if its aims are met, or rapid
backpedalling if military efforts do not proceed as expected. Entry and
exit points would be flexible and tailored to combining military effects
and political/diplomatic efforts. In any case, conflict would proceed
on a broader stage, and would involve posturing in the international
community, and posturing to its own citizens. If it appeared to be
failing in its military objectives, the degree to which it could save
face through some accommodation might be the difference between an
uneasy peace and escalation of the conflict to a new level of violence.

Bitzinger and Gill lay out four levels of conventional scenarios:

- Low-level intimidation: exercises, weapons tests, subversion
or espionage, etc. We have seen this level of action
before: the missile tests of 1996, for example.
- A naval blockade which would hurt Taiwan’s economy.
- Missile strikes and other limited direction action to coerce
and punish.
- An invasion to forcibly extend PRC control to Taiwan.

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99 Richard Bitzinger and Bates Gill, Gearing up for High-Tech
Warfare? Chinese and Taiwanese Defense Modernization and Implications
(Continued on the next page).
Klintworth adds to and refines this list of options. Intimidation exercises would "demonstrate to Taiwan and the region, but especially to the United States, that the PLA has the capability and resolve to attack Taiwan if necessary." Attacks on offshore islands are also an option,100 as we saw in the periodic shelling in 1954-1955 and 1958.

Jencks adds a variety of unconventional options to the scenario list. A high-altitude nuclear burst would create an electromagnetic pulse (EMP) that could destroy or disable much of Taiwan’s communications and information infrastructure. What Jencks terms an "electronic blackout" could be used alone, as economic intimidation, or in conjunction with conventional actions – limited attacks, a blockade, or outright invasion. To this scenario we could add computer network attack, which has a large and robust representation in Chinese strategic thought.101

Jencks discounts the use of high-altitude EMP against U.S. forces in the region, judging that the hardened U.S. forces would not be decisively degraded, and the action would provoke a more serious U.S. response. However, Jencks does not rule out a PLA nuclear attack on the U.S. military – a naval fleet or isolated airbase. The United States would have a difficult time finding a proportionate response to such an action, and an all-out attack on China would run the risk of provoking a destructive second strike from China. While a few years ago it was possible to argue that the United States could have destroyed PLA

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101 See Cliff et al., Entering the Dragon’s Lair: Implications of Chinese Antiaccess Strategies, pp. 54-56.
nuclear retaliation capability with a high degree of confidence,\textsuperscript{102} the proliferation of the road-mobile DF-31 would make a U.S. disarming strike difficult if not impossible.

How feasible might these unconventional scenarios be? Special operations forces (SOF) attacks in isolation (e.g. directed against Taiwan leadership) may be too risky – only an unlikely chain of events would lead to Chinese success, and a failure may precipitate an outright move towards independence that would be backed by the international community. An electromagnetic pulse (EMP) attack would mean that China would be crossing the nuclear threshold, a very serious event for a low likelihood of payoff.\textsuperscript{103} But that a full-scale amphibious assault, "decapitating" SOF attacks, or unconventional EMP employment look unrealistic does not mean that Taiwan is secure. The most likely to succeed with the least risk to Chinese policy may be either an outright invasion, or an extended coercion or punishment campaign including a blockade.\textsuperscript{104} Assisting Taiwan in resisting either of these courses of action would require the U.S. military to secure air and sea superiority in the area around Taiwan and its lines of communication.

**Amphibious Assault**

Perhaps the most-discussed Chinese option is an amphibious assault to directly defeat Taiwan’s army, occupy the island, and integrate the population into the PRC. This option would be very difficult for China to execute – with or without U.S. help to Taiwan. In the near term, the PLA likely does not have sufficient sealift to prosecute an outright invasion with a high degree of certainty.\textsuperscript{105} In the near future, a

\begin{itemize}
\item[\textsuperscript{103}] Bush and O’Hanlon, \textit{A War Like No Other: the Truth About China’s Challenge to America}, pp. 135-136.
\item[\textsuperscript{104}] Bush and O’Hanlon, \textit{A War Like No Other: the Truth About China’s Challenge to America}, pp. 158-159.
\item[\textsuperscript{105}] Based on OSD, \textit{Military Power of the People’s Republic of China 2008}, p. 54, and Cordesman and Kleiber, \textit{Chinese Military Modernization}, p. 131, the PRC’s current sealift capacity is 26 LSTs and 28 medium landing ships, for a total sealift capacity of 15,000 men and 620 tanks.
\end{itemize}
landing may only be feasible as the coup de grace to a regime and military already defeated by other means, or as an unopposed landing, post-capitulation, intended to drop off an occupation force. A smaller-scale landing could be part of a special operations gambit, to assassinate leaders or seize key infrastructure – either alone or part of a larger military campaign. However, in the medium to long term, a concerted effort to bolster its amphibious capabilities could make this option more robust. While for the time being other possibilities may be more attractive to Chinese decisionmakers (notably extended coercion/punishment options like a blockade, aerial campaign, intermittent missile strikes, etc.), nevertheless, we cannot ignore the amphibious option as it is arguably the most existential threat to Taiwan. While it would be helpful for Taiwan to invest in the capabilities to oppose an amphibious landing themselves,\textsuperscript{106} USAF airpower would have an important role.

**Blockade**

China could use a blockade of Taiwan’s ports to bring its economy to a standstill and coerce Taiwan into entering negotiations over its status (on China’s terms). A blockade would be an attractive option for

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\textsuperscript{106} Taiwan’s most effective options would target ships when they are most vulnerable - while they are offloading men and cargo (stationary targets on the beach are much easier to locate and destroy than moving ships at sea). Artillery, attack helicopters, and mobile surface-surface missiles could be very effective in this role.
several reasons. It would be an “economy of force” option—creating a strategic effect with relatively little commitment (at least compared to a full-scale invasion). A blockade would be less risky than an outright invasion, coup de main, or unconventional scenario. From China’s perspective, the consequences of a failed blockade would be unfavorable, but not nearly as dire as a failed invasion or assassination campaign. Those scenarios would dramatically hurt China’s prestige in the international system, whereas a blockade could be justified rhetorically.\textsuperscript{107} Of course, if faced with failure, China could always escalate beyond the confines of a limited blockade.

In order to be effective, a blockade could still be “leaky.”\textsuperscript{108} It would only need to put any ship or airplane intending to transit Taiwan at considerable risk—it need not literally seal off the island. This key observation means that a blockade could be difficult to defeat. It would not be enough to deny China persistent air and sea superiority because they would only need it intermittently. The outright defeat of a Chinese air and sea blockade would require U.S. forces to secure persistent air and sea superiority, a task that would require the considerable use of U.S. air and sea power.

\textbf{COMPONENT AIR CAMPAIGN}

Ongoing RAND work has characterized what PLA doctrinal and operational writings suggest a use of force against Taiwan (including the possibility of U.S. intervention) might look like.\textsuperscript{109}

Any PRC use of force “would likely begin with an offensive air campaign against the island.”\textsuperscript{110} If the United States were to

\begin{footnotesize}
\begin{itemize}
\item \textsuperscript{107} Bush and O’Hanlon, A War Like No Other: the Truth About China’s Challenge to America, pp. 133-134.
\item \textsuperscript{108} Bush and O’Hanlon, A War Like No Other: the Truth About China’s Challenge to America, p. 132.
\item \textsuperscript{109} Roger Cliff, John Fei, Jeff Hagen, Elizabeth Hague, Eric Heginbotham, and John Stillion, Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century. Santa Monica: RAND, forthcoming publication.
\item \textsuperscript{110} Cliff et al., Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century.
\end{itemize}
\end{footnotesize}
intervene, China "would likely conduct a similar offensive air campaign against U.S. forces in the western Pacific."111 We should also not discount the possibility of PRC preemption. If China perceives that the United States would intervene or was moving to intervene, it may choose to begin such an air campaign before the United States has actually commenced hostilities. This would be consistent with past Chinese military behavior – e.g., intervention in the Korean War – which China has seen as strategically defensive, while operationally offensive. The goal of attacking military facilities on Okinawa would simply be to prevent U.S. (and Japanese) forces there from intervening in a Chinese use of force to resolve what Beijing regards as an internal matter.112

The first objective of such a campaign would be to seize air superiority through attacks on air defense firepower, early warning, command and control, airbases, and aircraft on the ground.113 Subsequent objectives would be determined by what China’s overall plan was – outright invasion, blockade, or punishment/coercion. A centerpiece of a blockade or punishment/coercion campaign would be the seizure and enforcement of PLA air dominance over Taiwan, including an exclusion zone and the interception of any unauthorized flights to or from the island.114 An air campaign preluding a landing would seek to seize and hold air superiority to allow the safe transit of sufficient men and materiel to attain a decisive lodgment on the island. An air campaign could also prelude an airborne campaign aimed at leadership and key nodes on Taiwan. In this case, the air campaign would seize air superiority between the points of embarkation and debarkation. An airborne campaign may occur in concert with an amphibious landing.115

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111 Ibid.
112 Ibid.
113 Ibid.
114 Ibid.
POSSIBLE U.S. OPTIONS

Regardless what form potential Chinese action against Taiwan could take, U.S. airpower would clearly play a part countering it. Significant U.S. combat power ready to respond to aggression in theater, if protected from anti-access threats, would present credible force options against PRC aggression. If the United States were to intervene, the USAF would need to counter key PLA goals:

- In the case of PLA intimidation actions and prior to all other scenarios:
  - Present credible use of force options before hostilities commence.

- In all scenarios:
  - Deny information superiority, and seek U.S. and Taiwanese information superiority.

- In all scenarios other than intimidation or coercion through low-level missile strikes:
  - Deny air superiority and seek U.S./Taiwanese air superiority.

- In blockade scenarios:
  - Open a PLA blockade, deny PLA ability to blockade again.

- In an invasion scenario:
  - Interdict an invasion fleet, deny PLA capability to invade.

- In all scenarios, including extended coercion/punishment:
  - Reassure Taiwan, signal that the United States can and will credibly protect Taiwan.

The USAF would play a part in countering PLA information campaigns. Pursuing information superiority would also require a robust, survivable USAF ISR presence. Opening a naval blockade would be largely up to the USN, although the USAF would be needed to counter PLAAF and PLANAF air superiority pursuant to that blockade, as well as to cover USN assets from PLAAF and PLANAF attacks. Interdicting an invasion fleet and PLA resupply would be a cooperative Navy and USAF endeavor.
Opening an aerial blockade or a combined air/sea blockade, denying enemy air superiority, and pursuing our own air superiority would possibly be the most challenging operational goal to pursue. Pursuing these operational goals would require USAF air superiority fighters operating in sufficient numbers to deny PLA aircraft air superiority over Taiwan. PLA anti-access threats, especially its ballistic missile force, are most severe where USAF air superiority assets would be most optimally based – at Kadena AB and other airbases close to the area of operations.

The actions listed above are just a sample of possible U.S. operational goals. Obviously, which goals are pursued would depend on the PRC course of action. If the PRC realized that the United States had the ability to achieve its operational goals, it would be much less likely to act. Robust U.S. capabilities would help alter China’s strategic calculus in favor of alternative, more peaceful courses of action.

If the United States were not able to achieve the goals above, we would have to depend on some other form of deterrence. This could be difficult. If China were to pursue a hostile course of action, it would have already decided that the Taiwan issue was more important than the grave damage hostile action would inflict on the PRC economy and relations with other countries. The cost-benefit calculus implicit in such a decision, coupled with the asymmetry of interests between the United States and PRC, would make deterrence through threats of punishment or retaliation a very tricky matter.

**PLA ATTACKS**

If the United States did choose to intervene militarily in a China-Taiwan conflict, PLA attacks against U.S. facilities in the western Pacific would be a likely opening move. Cliff, et al., find that an air campaign would begin with information reconnaissance and an information offensive. These actions could include probing adversary’s networks and information systems, taking actions to degrade adversary’s access to intelligence, and pursuing psychological operations aimed at adversary militaries and populations. The opening firepower would likely be
delivered by ballistic missile – extended range DF-15s (CSS-6) are capable of reaching Okinawa. Missiles attacking aircraft in the open would be armed with flechette submunitions. Missiles with penetrating submunitions would attack runways, hangars, and partially-buried fuel tanks.\textsuperscript{116}

Cruise missile and fixed-wing aviation attacks would follow the ballistic missile barrage. These attacks are more easily intercepted by fixed-wing aviation, but if USAF aircraft were grounded or destroyed, the PLA AF would have a window of opportunity.

Given the current state of hardening and the difficulty of developing and fielding truly effective active defenses, an initial Chinese attack such as that described above would be difficult to counter. The likely result would be that USAF infrastructure on Okinawa would be severely damaged. We explore the likely effects of these attacks in the next chapter.

\textsuperscript{116} Cliff et al., \textit{Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century}. 
4. THEATER ACCESS CHALLENGES

INTRODUCTION

If the U.S. military were called upon to protect Taiwan, it would need safe, secure operating bases. However, the USAF could lose access to vital locations, particularly airfields, in a variety of ways. Regional allies could defect or be coerced into denying U.S. forces the use of bases on their territory. China could attack U.S. bases and staging areas: OSD reports that the PLA is seeking to build the capability to degrade a potential adversary’s force generation and sustainment by holding at risk or striking aircraft carriers, logistics nodes, and regional bases.\textsuperscript{117} Several works have discussed these emerging threats to airbase access and how to deal with them. While this dissertation does not pursue any original work in this area, a brief review of the research others have done on USAF airbase vulnerability will highlight the problems the USAF may face when operating close to Chinese territory. This discussion will also motivate the likelihood that bases outside the (most intense) threat ring, especially Andersen AFB, will be the only places available to USAF forces in a hypothetical China-Taiwan conflict. This chapter will highlight the major challenges facing USAF facilities in the western Pacific: political access, the special operations threat, the ballistic missile threat, and the cruise missile threat; the likelihood that threatened bases will be unusable in a contingency; and what the fallback may be.

POLITICAL ACCESS

Political access is an issue in the western Pacific since the U.S. airbases closest to Taiwan are on Japanese soil. Japan may be very nervous taking such a step given its proximity to China and China’s growing regional power. The dilemma would be similar for other

\textsuperscript{117} OSD, Military Power of the People’s Republic of China 2008, p. 31.
prospective allies like the Philippines. While for the time being, it looks likely that Japan will allow the United States to use facilities on its territory, we cannot assume that access will be guaranteed in the future.

Cliff, et al., pointed out that “Chinese strategists identify reliance on allies for assistance and support, including access to forward bases, as a major vulnerability in U.S. strategy.” The writings reviewed did not identify specific diplomatic actions, but did make clear that efforts would be made to split the United States from its allies and the bases they would provide. It appears that Chinese strategists are well aware that denying the USAF the use of allies’ airfields would greatly hinder the amount of power that the USAF could project.119

The main target of any Chinese effort to split the United States from its allies would clearly be Japan. The reason is clear: the only current U.S. military bases proximate to Taiwan are in Japan. It is unknown what form this effort may take, but Cliff, et al., postulate that the PRC would attempt to deter or coerce Japanese behavior, perhaps threatening strikes on Japan itself.120 Taking a longer-term view, it is also possible that power changes in the region could realign alliances. Though Japan would certainly be a target of diplomatic


119 Cliff et al., Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States, p. 77.

120 Cliff et al., Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States, pp. 78-79.
efforts in this case as well, the work may already have been done by changes in the regional security system. The latter form of hypothetical “anti-access,” a longer-term shift in the security landscape, would occur over years and perhaps decades. While this is outside the timeline of a contingency for which the United States would need to develop specific response plans, it is inside the timeline of USAF weapons purchases – decisions which may rely on a specific operating context that could vanish if the U.S.-Japanese alliance were to weaken considerably.

Paradoxically, the longer-term case for a U.S.-Japanese alliance, and the access that comes with it, would be bolstered by a robust capability to operate without Japanese bases. There is a high correlation between the capabilities required to defend Taiwan and the capabilities required to defend Japan. If the U.S. military could deliver those capabilities with or without local base access, our ability to meet our security commitment to Japan would be robust against Chinese threats to Japanese airbases. The U.S.-Japanese alliance is the key feature of our security strategy in the Pacific. Keeping the alliance with Japan healthy goes far beyond simply assuring access for USAF aircraft – the alliance itself is more important than access, especially in light of the physical threats to airfields. The United States needs to explore any policy actions that could forestall a long-term abdication of Japan from the U.S.-Japan alliance or that could mitigate the consequences of Chinese deterrence or coercion against Japan.

THREATS TO AIRBASSES

Cliff, et al., find that in order to “defeat a technologically superior enemy, such as the United States, the PLA has focused on devising strategies that maximize China’s relative strengths and that create opportunities to exploit adversary weaknesses.” One key dependency is the reliance on airbases, an observation which the study
shows is prevalent in Chinese doctrinal writings.\textsuperscript{121} Chinese thought regards attacks on airbases as consistent with a defensive orientation: "Nothing would bolster air defense more than neutralization of the enemy’s airbases and aircraft carriers."\textsuperscript{122} Bowie found that military threats are especially problematic for fighter operations - since they typically require bases no more than 1,000 to 1,500 nautical miles from the enemy.\textsuperscript{123}

USAF airbases have evolved into highly efficient sortie-generation mechanisms. Yet many of the lessons in robustness that the USAF learned in WWII and the Cold War have been deemphasized. USAF airbases are very good at maximizing the number of sorties that are flown each day, but are less good at sustaining damage. This is not surprising - the United States has not really faced a competent (conventional) adversary since the end of the Cold War. And in the current era where national attention and military budgets are focused on insurgencies, it will be difficult to pursue the measures necessary to make USAF airbases in the Pacific robust to antiaccess attacks.

The next sections will explore specific threats to airbases, including special operations forces, China’s sizeable conventional ballistic missile arsenal, and cruise missiles.\textsuperscript{124}

\textsuperscript{121} Cliff et al., \textit{Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States.}


\textsuperscript{123} For an excellent discussion of the problems with long-range missions, see Christopher Bowie, \textit{The Antiaccess Threat and Theater Airbases}, Washington, Center for Strategic and Budgetary Assessments, 2002, pp. 11-15.

\textsuperscript{124} Nuclear weapon use is not considered in this dissertation. Using nuclear weapons would elevate the issue beyond the limited conflict studied herein. While the possibility cannot be completely ignored, it is hard to imagine how Chinese leaders could develop a decision calculus that encouraged nuclear first-use. The stakes are not high enough, and Chinese strategic thought emphasizes not only rapidly escalating, but also rapidly de-escalating to achieve political aims. Nuclear use would remove the ability of China to de-escalate.
Cliff, et al., found that Chinese SOF would likely play a role in attacking air bases, at least according to the sources they reviewed. SOF would perform reconnaissance, harassment, and perhaps direct attacks on aircraft, facilities, and personnel.\(^{125}\)

Vick documented a long history of ground attacks on airbases, finding that ground attacks were more frequent than commonly appreciated and that the most common targets were aircraft themselves.\(^{126}\) Shlapak and Vick confirm that ground attacks have been effective in harassing airbase operations in the past, but note that emerging capabilities make the threat more serious than in the past. These include man-portable air defenses (MANPADs), rocket-propelled grenades (RPGs), more accurate (precision-guided) mortars, and large-caliber sniper rifles. To this list, this author also adds portable electromagnetic weapons.\(^{127}\) All of these technologies enable standoff attacks in particular, and USAF reliance on expensive, low-density force enablers (ISR, AWACS, tankers) would make the effectiveness of such attacks disproportionately high.\(^{128}\) Such attacks would be difficult to counter, and future adversaries may

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\(^{125}\) Cliff et al., *Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States*, p. 63.  
\(^{127}\) Electro-magnetic weapons present an interesting case because they could hypothetically disrupt electronic components of aircraft and communications systems without causing human casualties. Therefore, they may be a more palatable way to initiate a first strike. There is also a plausible-deniability advantage: firing ballistic missiles from mainland China is hard to conceal, but employing a SOF-delivered electromagnetic weapon could be denied or spun as a U.S. military accident. Sophisticated observers would know the difference, but the world stage may not. While the basic principles are not difficult to engineer, there is uncertainty surrounding the effects of such weapons and the electromagnetic hardness of U.S. military equipment. The effects could range from no disruption at all, a system reboot, or in the most extensive case – burned-out electronic components. Poor delivery, insufficient power, insufficient range, or robust hardening would degrade performance. Lacking insight into these issues, this analysis notes the possibility without delving deeper.  
take advantage of these relatively economic means of inflicting damage on the USAF.

The threats outlined by Shlapak and Vick are especially acute in the western Pacific. U.S. bases in Okinawa are in heavily populated areas or not far removed from them. For example, a visit to Kadena AB showed multiple vulnerabilities, especially line-of-sight issues presented by high-rise buildings immediately off base. Well-trained SOF armed with sniper rifles might be able to target radars of AWACS aircraft; rocket-propelled grenades could damage or destroy airframes. The aerial view of a part of Kadena shows how close heavily populated areas are to parking ramps - including several high rises. The opportunities for mayhem that a SOF presence on Okinawa would present could make the effort worthwhile. A similar story could be told for other facilities in the western Pacific.

**Figure 3**
Partial Aerial View of Kadena AB

Indeed, Andersen AFB is not completely immune from the SOF threat. While the Andersen flightline is further from populated areas, the

\[^{129}\text{Image from <http://www.globalsecurity.org/military/facility/kadena.htm>}.\]
infiltration problem is likely more severe. Guam has become a major transit point for human smuggling from the PRC.\textsuperscript{130}

SOF attacks are potentially attractive for several reasons – they are an “economy of force” option. A successful airbase attack, in which aircraft were destroyed or operations were slowed for a time (especially at a critical time), would have a high return on investment. They also diversify attack options, complicating a defender’s strategy. And, depending on the type of attack, they could be publicly disavowed. Where an overt Chinese ballistic missile attack on Andersen AFB, for example, would clearly draw the fury of the American public, the PRC might think that an “accident” would not. Plausible deniability may be an important asset for a covert attack, one which might allow China options to achieve effects before formal hostilities have commenced while lowering the probability of retaliation.

Countering the SOF threat would be best achieved by a combination of passive hardening measures, active defenses, and enhancing cooperation with local law enforcement and military personnel.

Increasing passive defenses on-base would complicate SOF attacks. Measures such as hardened aircraft shelters and underground fuel storage are prudent anyway because of bases’ vulnerability to ballistic missiles and other strikes – their utility in protecting against SOF is a “freebie.” Parking aircraft in hardened aircraft shelters reduces their exposure to standoff attacks or SOF armed with high-caliber rifles. Hardened command facilities accomplish the same for personnel. Above-ground fuel storage may be very vulnerable to SOF armed with RPGs or mortars. Cliff, et al., recommended that “the United States should ensure that any air bases in the western Pacific likely to be used in a conflict with China have sufficient underground fuel storage to sustain several weeks of high-intensity operations.”\textsuperscript{131}


\textsuperscript{131} Cliff et al., \textit{Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States}, p. 97.
Another key initiative would be increasing cooperation with off-base security forces. Cliff, et al., notes that most attacks would initiate from host-nation territory, and recommends developing the mechanisms to smoothly integrate with host-nation forces.\footnote{Cliff et al., \textit{Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States}, p. 100.} If we include Andersen AFB, we can generalize to include the Guam Army National Guard, particularly the 1st Battalion, 294th Infantry. These forces, in partnership with base security forces, would greatly enhance the ability to defend the Andersen AFB perimeter and off-base key points from covert attack.

Shlapak and Vick recommend better situational awareness (i.e., improved surveillance) and enhanced mobility for base security forces – including vehicle mounted heavy weapons – as counters to a penetrating SOF attack. To protect against the standoff threat, they envision an approach with three elements: confounding the attack using decoys, rotating aircraft between bases, and varying operations; detecting and defeating the threat before it launches the attack (which would include freeing up security forces for off-base action by relying more on users to provide their own security – e.g. arming maintenance personnel and tasking them with defending the facilities they use); and hardening facilities against the threat, as we have discussed above.\footnote{Shlapak and Vick, \textit{Check Six Begins on the Ground: Responding to the Evolving Threat to U.S. Air Force Bases}, pp. xv to xvi.}

### The Ballistic Missile Threat

Cliff, et al., finds that attacks on air bases are an important element of Chinese doctrine. Targets would include runways, aircraft, fuel, and other critical nodes in the system that puts planes in the air. The work also points out that Chinese strategists see ballistic missiles as particularly effective because of the difficulty of countering their use.\footnote{Cliff et al., \textit{Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States}, pp. 62-63.}
The DF-15 (also known as the M-9 or CSS-6) is one of China’s primary theater ballistic missiles. Its base variant is capable of delivering an 1,100lb warhead to targets 600km away, farther for later variants (reportedly capable of reaching Kadena AB). Older versions have CEPs in the 150m-500m range, though these have probably been improved to between 30m and 50m. Cliff, et al., calls attention to the reported development of an extended-range DF-15 armed with submunitions and capable of a CEP less than 50 meters. China is believed to have 315-355 DF-15 missiles, and is building more. OSD reports that China is building 100 SRBMs a year, but this number includes the DF-11 (aka CSS-7) which cannot range U.S. facilities. How many DF-15s in China’s inventory are of the extended-range variety, and how many have been outfitted with submunition warheads, is unknown.

Less numerous, but still concerning, is the DF-21 (aka CSS-5). The land attack version can deliver a 1,300-lb warhead 1,100+ miles, making it capable of reaching all of Japan, all of the Philippines but the southern tip of Mindanao, virtually all of Indochina, and parts of Malaysia. China is believed to have about 60-80 of these missiles in the inventory, although the rate of production of new systems is unknown.

The DF-21 is now primarily a nuclear-armed missile, but there is no reason that China could not arm them with conventional warheads as we have seen with other systems. Indeed, China has already expanded the role of these medium-range ballistic missiles: OSD’s 2008 Report, for the first time, makes mention of a Chinese anti-ship ballistic missile,

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136 Ibid.  
137 Cliff et al., Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States, p. 63.  
based on a modified DF-21.\textsuperscript{140} For a conventionally-armed ballistic missile to be useful against a military target, its accuracy needs to be better than what an unguided missile can achieve. The CEP of the basic DF-21 is reported to be between 300m and 700m,\textsuperscript{141} slightly better but in the same class as the familiar Scud. To achieve much better accuracy requires the use of maneuvering reentry vehicles to deliver the warhead. We can infer that the ASBM version of this missile has a maneuvering reentry vehicle if it is to have any hope of hitting an aircraft carrier or large ship. It would not be challenging to apply a similar (but slightly less demanding) design to a conventional, land-attack version.


China’s ballistic missile inventory is especially concerning if we consider the threat that they would pose when armed with specialized warheads. Stillion and Orletsky found that missiles armed with submunitions are much more effective at attacking unsheltered aircraft than missiles armed with unitary warheads. Aircraft are soft targets – large overpressures are not required to render them inoperable, only some fragmentation damage. Further, the relatively large size of an airplane (vs. a human target) means that a tight dispersal pattern is not necessary – a submunition warhead attacking parked aircraft can cover a large area: “An 1,100-pound M-9 (DF-15) ballistic-missile warhead covers almost eight times the area when using a submunition warhead than when using a unitary warhead.”\textsuperscript{143} The authors also found


\textsuperscript{143} Assuming a “20-foot lethal radius for a 1-pound submunition and that 75 percent of warhead weight is devoted to submunitions, with the

\textsuperscript{143} Assuming a “20-foot lethal radius for a 1-pound submunition and that 75 percent of warhead weight is devoted to submunitions, with the
that improvements in missile guidance could be combined with submunition warheads to make existing missile forces more lethal.\footnote{Stillion and Orletsky, \textit{Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks}, p. xiii.} Figure 5, taken from their work, shows the footprint of a submunition-armed DF-15 on a hypothetical aircraft parking ramp. The largest circle is the DF-15’s lethal area if armed with submunitions. The small, grey circle in the bottom left is the lethal area of the DF-15 armed with a unitary warhead (the other circles are unrelated, hypothetical airfield-attack weapons). Figure 6 shows the lethal area of a submunition-armed DF-15 superimposed onto part of the ramp at Kadena AB.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure5.png}
\caption{Footprint of a Hypothetical Submunition-Armed DF-15\footnote{Stillion and Orletsky, \textit{Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks}, p. 14. Depiction of aircraft parking is for illustration purposes only.}}
\end{figure}
These figures show the enormous areas that a submunition-armed DF-15 could attack. The figures also suggest how few warheads would be required to do an enormous amount of damage to parked aircraft. Ongoing work shows that only 34 DF-15 missiles armed with submunitions would be necessary to severely damage or destroy every aircraft parked in the open at Kadena AB. Kadena AB is the largest USAF airbase in the theater (in terms of paved surface area) – so this number would be less for any alternate locations.

The missiles required to attack Kadena alone are a small fraction of the total Chinese inventory of these systems, which calls into question the efficacy of interdicting these systems before or after they could be launched at USAF facilities. Planning to destroy mobile launchers (TELs) would be insufficient. Vick, et al., make a convincing

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146 John Stillion and Lauren Caston, "Operating Airbases Under Attack." Internal RAND Briefing. Results will be in a forthcoming RAND report.
case that operations against PLA TELs will be very difficult. While the USAF had a very difficult time finding and targeting mobile forces in Kosovo, the TBM operating area opposite Taiwan is 30 times the area of Kosovo, vastly compounding the problem. The line-of-sight issues presented by Fujian province’s rough terrain would limit standoff ISR’s ability to detect TELs operating inland, and Chinese air defenses would prohibit most USAF ISR assets from penetrating to get a good overhead look. And given the fleeting nature of a mobile target deep inland, it is doubtful that attack aircraft could even respond to a target in time to destroy it. Even if new concepts prove fungible, hunting TELs cannot fully protect Kadena AB from attack – the potential damage caused by leakers is just too significant, especially if significant combat power is deployed there. Note also that if the PRC attacks Kadena preemptively, the USAF will clearly not have had the chance to destroy the TELs before damage is done.

The potential damage that leakers could cause also calls into question the value of active defenses in the absence of passive defenses. Even if a Patriot Pac-3 interceptor were to have a reasonably good probability of a kill (Pk), active defenses alone would not be sufficient to counter a ballistic missile barrage. More effective ballistic missile interception would simply drive the attacker to saturate the defender’s defenses by launching more missiles or deploying decoys. Indeed, there are reports that the PLA has flight tested countermeasures, including decoys. Given that active defenses cannot be perfect – i.e. their Pk is something less than 1.0 – and that a finite number of attempted intercepts can occur at any given time, some missiles (perhaps many) would get through active defenses. Eventually, air defense batteries would run out of interceptors, unless enough were prepositioned to engage all of the 2nd Artillery several times over.

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Even with relatively robust active defenses, hardened shelters are needed to mitigate the effects of leakers. Passive defenses are critical to protecting key assets, especially aircraft. Parking USAF aircraft in the open within range of Chinese submunition-armed ballistic missiles invites disaster.

In part because of the extreme difficulties in intercepting ballistic missiles, much of the literature regards falling back to more secure locations as one of the most promising ways to deal with the ballistic missile threat. Stillion and Orletsky found that dispersal, hardening, and active defenses could mitigate the ballistic missile threat to some extent—though each option has serious drawbacks. They discuss a standoff option: a small number of bases with “assured access” (both through location and prior hardening) would be favorable if the USAF were to develop concepts to operate at very long ranges. The concept they discuss is a long-range, Mach 2 bomber.\textsuperscript{149} Bowie also finds that falling back on bases outside the threat (if sufficient force can come from those bases) is a potential workaround.\textsuperscript{150}

Kadena AB and other bases on Okinawa are exposed to the most serious threat, in terms of the numbers of Chinese missiles. The primary threat to Okinawan airbases, the DF-15, cannot range many locations in mainland Japan or in the Philippines. But that is not to say that other regional bases, or potential contingency locations, are not exposed as well. The DF-21, in particular, could be used to hold a variety of USAF facilities or potential contingency locations at risk—especially given the very small numbers of submunition warheads required to inflict a grave amount of damage to aircraft parked in the open.

There is no reason to assume that, given the efficacy of such weapons, that China will not produce more; convert some even longer-range weapons to conventional, airfield-attack duty; or build newer, conventional longer-range missiles. China has both the technical capacity and the motive to do so.

\textsuperscript{149} Stillion and Orletsky, \textit{Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks}.
\textsuperscript{150} Bowie, \textit{The Antiaccess Threat and Theater Airbases}. 
Cruise Missiles

Cruise missiles are a significant airbase attack threat, and are perfectly suited for attacking large, fixed targets like airbases. OSD reports that "China is developing air- and ground-launched land attack cruise missiles for standoff, precision strikes."\(^{151}\)

The DH-10 is the primary land-based cruise missile threat. The DH-10 is comparable to the U.S. Tomahawk, and uses terrain contour matching guidance. If fired from the Chinese mainland, it could reach all of Japan, the Philippines, and Indochina to the Malacca Strait. In other words, every USAF airbase in the region – save Andersen AFB – is in range of DH-10s fired from the mainland. Current DoD estimates put China’s DH-10 inventory at 50-250.\(^{152}\) A DH-10 cruise missile has a warhead comparable in size to a DF-15 – meaning a submunition-armed DH-10 would have roughly the same effect as a submunition-armed DF-15 ballistic missile (though the dispersal pattern would be somewhat different). If we take the high end of the estimated inventory, assuming that it will be fulfilled in the near future if not already, China’s ground-launched DH-10 arsenal alone could attack the parking areas at 12 Kadena-sized locations. DH-10 CEP is reported variously from 10-15 m.\(^{153}\) This accuracy is more than adequate for the area-attack role, and is also adequate to strike hardened aircraft shelters.

One of the more concerning possibilities for bases relatively removed from the Taiwan area of operations are H-6 bombers armed with long-range cruise missiles. In fact, the new H-6H variant is reportedly optimized solely for the cruise-missile launching role. Kopp finds that "While the [H-6] Badger is not a credible penetrator armed with free fall bombs, if armed with a modern 600 nm class conventional cruise

\(^{151}\) OSD, Military Power of the People’s Republic of China 2008, p. 34.
\(^{152}\) OSD, Military Power of the People’s Republic of China 2008, p. 56.
\(^{153}\) CEP reported by Wendell Minnick, “China tests new land-attack cruise missile,” Jane’s Defence, accessible at <http://www.janes.com/defence/news/jmr/jmr040921_1_n.shtml>. For a discussion of the implications of CEP on targeting USAF hardened aircraft shelters, see the subsequent page.
missile, or 1,300 nm class nuclear-armed cruise missile, it becomes a credible strategic strike asset offering a reach of 1,900 to 2,600 nm.\textsuperscript{154} H-6 aircraft armed with cruise missiles could threaten any U.S. installation in the western Pacific, including installations on Guam. Even Hickam AFB in the central Pacific could be vulnerable to Chinese submarine-launched cruise missiles (a potential future capability).

PLA cruise missiles could be armed with unitary warheads or submunition warheads.\textsuperscript{155} We have seen that submunitions would be particularly devastating to aircraft parked in the open. Cruise missiles can achieve lower CEPs relative to ballistic missiles – making them well suited to attacking structures that require direct hits or near misses with the large overpressures associated with unitary warheads. If China can achieve a 15m CEP guidance accuracy, a single DH-10 armed with a 1,000 lb TNT warhead has a .8 Pk against any hardened aircraft shelters on a U.S. or Japanese installation. If Chinese CEP is as bad as 25m, 2 DH-10s fired at a shelter would still have a 69% chance of destroying it.\textsuperscript{156} While subsonic cruise missiles are easier to intercept than ballistic missiles, in significant numbers or in the absence of an interception capability, they become problematic.

The current USAF CONOP for cruise missile defense calls for layers of interceptors – the F-22 is the most capable aircraft for this mission – supported by JSTARS for detection.\textsuperscript{157} This CONOP relies on those aircraft being present, and Cliff, et al., note that if air operations were hindered by other attack methods, airborne cruise missile defense would not be viable. Defenses could also be overwhelmed by large

\begin{footnotesize}
\begin{enumerate}
\item These calculations assume no interception by ground-based defenses or aircraft. Interception is treated parametrically when aggregating the effects of multiple weapon firings. Explosives more powerful than TNT increase performance slightly. See Appendix E for calculation method.  
\item Bowie, \textit{The Antiaccess Threat and Theater Airbases}, p. 63.
\end{enumerate}
\end{footnotesize}
numbers of cruise missiles fired at once. Enhanced shipborne defenses and land-based systems could fill the gap, and provide robustness. Airborne cruise missile defense subtracts critical assets from other missions where they are needed. This is especially significant considering how thinly USAF aircraft will likely be stretched if they must operate from standoff airbases further from Taiwan (as we will explore subsequently). The problem is further compounded if USAF operations are dispersed among a large number of bases. If bases are far enough apart that they cannot share a regional or point cruise missile defense, warfighters may have to dedicate inordinate resources to adequately defend each dispersal airbase separately.

CONCLUSIONS

This chapter reviewed several of the more significant threats to USAF facilities in East Asia. The most severe threats are at bases relatively close to China (e.g. Kadena AB), but this is not a reason to ignore the significant threats to airbases further away from China. Two elements of the antiaccess problem motivate the possibility that the only available operating location will be Andersen AFB: the significant attack threat and the possibility that diplomatic efforts to split the United States from partners will be successful. Either of these elements is significant enough to remove the United States from much of the western Pacific.

There are different rings of threat severity. The first, and most severe, is anything within the footprint of extended-range DF-15s. These systems are numerous, with an inventory adequate to attack U.S. facilities on Okinawa facilities several times over. The extent of the threat to Kadena AB and the lack of hardening measures – besides a paltry 15 hardened aircraft shelters, makes it very likely that any serious ballistic missile barrage would destroy or damage most of the aircraft parked at that base. For this reason, any contingency pitting

158 Cliff et al., Entering the Dragon’s Lair: Chinese Antiaccess Strategies and Their Implications for the United States, p. 105.
the United States against China would have to be prosecuted primarily from bases further from the threat.

It may be tempting to simply disperse operations to other locations in the Japanese main islands, Iwo To, the Philippines, or perhaps Thailand. There are several permanent facilities in Japan that might support operations – Marine Corps Air Station Iwakuni, Yokota AB, and Misawa AB for example, along with Japan Air Self-Defense Force facilities that may be put on loan. Potential locations to develop in Japan may include the island Iwo To. Looking to other countries, the USAF could operate from host-nation airbases or civilian airfields – though these options would require a significant deployment of equipment to make up for a lack of infrastructure at expeditionary locations. A dispersed strategy may well have its advantages – any of the locations mentioned above are less vulnerable to Chinese attack than Kadena AB or other Okinawan locations.

However, dispersal is not a panacea for anti-access challenges. Any potential base in Japan, the Philippines, or Indochina would be vulnerable to conventional DF-21 variants or DH-10 land-attack cruise missiles, or perhaps new, longer-range solid-fuel conventional rockets – which China has demonstrated the capability to build. These systems would be fewer in number, but could still put permanent facilities in Japan or potential expeditionary locations at significant risk. Attack by fixed-wing aviation is also a significant possibility, especially if operations have been disrupted or air-defense artillery destroyed by other attack modes. Any airfield within 1,100-1,200 miles of Taiwan can be held at significant risk from ballistic missiles and cruise missiles.

Andersen AFB is not immune. But the challenge does look less daunting than at bases in Okinawa, the rest of Japan, Iwo To, or possible Southeast Asia locations. The reasons are severalfold:

First, an attack on Guam is more difficult in terms of weapons and coordination. In terms of weapons, the land-based ballistic missiles that could reach Guam are currently relatively few in number, currently fill strategic nuclear deterrence roles, and are not well-suited to conventional attack (because of poor accuracy). Purpose-built conventional ballistic missiles intended for Guam would be more
expensive than the missiles that can reach Okinawa, and hence could be built in fewer numbers. Guam itself is vulnerable to air-launched cruise missiles, but launching a cruise missile attack from the air would multiply the operation’s complexity for China while increasing interception opportunities for the USAF.

Second, the warning time for an attack on Andersen would be longer than for an attack on Kadena. A longer warning would allow a better chance for aircraft to evacuate and base personnel to shelter before weapons actually started landing on the flightline. A longer warning time would also allow for the deployment of multi-layered active defenses, with multiple chances to interdict incoming missiles (as opposed to Kadena, where the proximity to China would allow only one chance to stop an incoming weapon). We previously dismissed active defenses as a complete solution, but when combined with a smaller Chinese arsenal, passive defenses, and evacuation opportunities, multi-layered active defenses could help mitigate the threat somewhat.

Third, Andersen’s distance from China may allow the USN to operate in the vicinity. The USN could help interdict missiles and attacking aircraft before they can damage their intended targets.

For at least the intermediate term, Guam is less vulnerable than Kadena, of course, but also any Japanese facilities or possible expeditionary locations. Guam’s relative safety could change if we see a push by the PLA to modify DF-31s, CSS-3, or other longer-range missiles for conventional attack roles; if we saw the development of new, conventional IRBMs; or if we observed the procurement of more-survivable long-range aircraft (like the Tu-22 Backfire, for example).

Further, the use of any base outside of U.S. territory is contingent on obtaining the approval of the host nation, and we have seen that diplomatic efforts to deny this permission will be part of a concerted Chinese effort aimed at changing the status of Taiwan. On the other hand, Guam is U.S. territory. When we think about the robustness of our force posture in the Pacific, it is the only place that we can be completely certain will not defect in the face of Chinese pressure. Even if host nation permission were forthcoming, the negotiations over rules of engagement would take time - time that the United States would
not have in a very short-notice situation. Opening expeditionary locations also takes significant time. The buildup to Desert Storm lasted months - and the airbase infrastructure in the Gulf region was large and well developed. While the USAF has made significant strides in quickly opening expeditionary locations, it is uncertain whether this can occur quickly enough in a denied-access environment to adequately respond to Chinese aggression or intimidation against Taiwan. Notwithstanding physical attacks, the only locations the United States can be absolutely sure of operating from are on U.S. territory - the closest being Andersen AFB on Guam.

When we consider the magnitude of the physical threat not only to Kadena AB, but also to other locations in Japan or hypothetical expeditionary locations elsewhere; along with the uncertainty that comes from depending on allies - there is a strong possibility that the United States will only have access to Andersen AFB on Guam. Determining the likelihood of this possibility is beyond the scope of this work, but the possibility is profound enough to merit investigation of its implications.
5. SORTIE GENERATION AND IMPLICATIONS

INTRODUCTION

The previous chapters have shown that despite encouraging signs, the potential for U.S.-China conflict still exists and if a conflict were to occur, it will probably be fought over Taiwan. USAF assets would be required to counter any invasion or coercive scenario. Chinese strategic thought indicates that air superiority is a necessary condition for such a campaign to succeed. As such, if the United States wishes to bring security and reassurance to Taiwan, the USAF needs to be prepared to deny China air superiority and, if possible, obtain air superiority for the United States. Further, effective ISR is a cornerstone of any operation. Unfortunately, the 2007 anti-satellite missile tests hint that the United States may need to rely on fixed-wing ISR. In the face of a PLAAF equipped to intercept these aircraft, USAF fighters would be required to protect these assets.

China’s anti-access efforts make it possible that the USAF will need to do this from standoff airbases – notably Andersen AFB on Guam. In order to examine the effects of operations constrained by anti-access, we must determine:

- To what extent flying operations are hindered operating from standoff locations.
- What flying operations from a standoff location can accomplish, and what vulnerabilities exist.

This chapter examines these questions in detail. In order to determine the force that Andersen AFB can produce, we utilize a sortie generation model (outlined in Appendix A). The throughput at any airbase is finite, and so, using this model, we can calculate the maximum number of fighters that could be on station over Taiwan.

The Andersen AFB sortie generation discussion, however, is only one piece of the expected effectiveness of air operations. The force that Andersen can bring to bear must be compared to the amount of Chinese airpower that we can expect to counter it. In order to make this
comparison, we use a similar sortie calculation for a postulated
PLAAF/PLANAF beddown. The analysis examines a 2015 scenario.\textsuperscript{159}

Once the force that the USAF and the PLAAF can bring to bear is
determined, we compare the two and judge whether or not the USAF can
achieve air superiority.

AVAILABILITY OF AIRBASES

U.S. military successes since the end of the Cold War have been
highly dependent on the contribution of air forces. This airpower has
relied on numerous secure bases within fighter range of the primary area
of operations. The potential for anti-access threats to deny the USAF
use of preferred facilities on Okinawa and other regions of Japan is
severe enough for us to consider an Andersen AFB-only scenario.

In a potential conflict with China in the western Pacific, it is
unlikely that extensive basing options will be available. The reasons
are twofold: the geography of the region precludes the ready
availability of a large number of potential airfields, and the threat to
airbases encompasses most close-in locations. There are very few

\textsuperscript{159} USN carrier aviation is not included in the air superiority
comparison over Taiwan. (For symmetry, PLAN aviation is not included in
the comparison either). Considerable pages have been dedicated to the
anti-access threats USAF airbases face. Much the same story can be told
for naval forces. The PLA has developed an anti-ship ballistic missile
based on the CSS-5, putting aircraft carriers at risk out to 1,500 km.
If able to operate inside the threat posed by ASBMs, the USN will need
to fend off numerous land-based aircraft armed with anti-ship cruise
missiles, many of which can be very lethal when combined with tactics
designed to overwhelm ships’ onboard defenses. If forced to operate
outside 1,500 km, naval aviation will not be able to contribute heavily
to the counter-air effort. And if using USAF tankers, USN aircraft will
be displacing USAF aircraft tailored more specifically to the air
superiority mission. The other option would be to use the F-18’s Aerial
Refueling System to “buddy-tank” each other, but this would cut sortie
generation considerably. If forced far back by anti-access threats,
naval aviation may only be able to contribute marginally to the air
superiority effort. On the other hand, if the Navy does choose to
operate closer to Taiwan, a significant portion (perhaps all) of its
available sorties may need to be dedicated to fighting off threatening
PLAN and PLAAF H-6s and JH-7s before they can fire the very capable YJ-
83 and AS-17 anti-ship cruise missiles, sea-skimming and capable of Mach
3.5 speeds.
islands within convenient fighter range of Taiwan – most of these are in the Ryukyus (e.g., Okinawa), which unfortunately are within range of China’s CSS-6 ballistic missiles. When we look to airbases further afield, few offer a compelling trade between a reduced threat and a reduced operating capacity. Between Kadena AB and Andersen AF, there is very little in terms of landmass. If we consider other U.S. facilities in the region – Iwakuni MCAS, Misawa AB, and Yokota AB – they are far from Taiwan yet relatively close to China. Misawa AB is the only truly hardened U.S. airfield in Japan, but it is almost as far from Taiwan as Andersen AF is. Facilities in Korea are hardened, but far from Taiwan, and it is questionable whether the USAF could operate out of Korea in a scenario involving Taiwan. Any of these facilities would involve a lengthy transit to Taiwan and require multiple tanker aircraft to operate very close to China. These tankers and any other aircraft transiting from these facilities toward Taiwan are at risk of being intercepted.

**CONTRASTING ANDERSEN AF AND KADENA AB**

In other words – most available bases are at the same time far from Taiwan, yet close to potential threats in China. Figure 7 shows the two main possibilities – Kadena AB in Japan and Andersen AF in Okinawa. Simple visual examination of the western Pacific will show the long distance from Andersen AF to postulated combat air patrol (CAP) locations over the Taiwan Strait. Whereas Kadena AB is only 450 nautical miles from the centerpoint of the Taiwan Strait, Andersen AF is 1,565 nautical miles distant. This location is at once a blessing and a curse. Its long distance makes it less vulnerable (though not invulnerable) to Chinese attacks, and also places it in a strategically valuable place ideal for bomber operations. Yet 1,565 nautical miles is a long way to fly a short-range fighter, which depends on refueling aircraft for extensions to its range.
Figure 8 contrasts the beddowns in Desert Storm with a possible Taiwan scenario. The line shown around the theater of operations is 450 nautical miles from the border of Iraq – roughly the distance from Kadena AB to the center point of the Taiwan Straits. The circles signify airbases which hosted USAF aircraft in Desert Storm, and

airbases available to the United States in the Pacific. This view makes two points apparent. First, operations in Desert Storm depended on many airbases. Many of these airbases were very large. The defense of Taiwan could not depend on a large basing infrastructure like the USAF had access to in the Middle East. Secondly, while in Desert Storm the USAF used numerous bases further than 450 nautical miles away, most of these bases hosted non-fighter aircraft – AWACs, ISR, tankers, bombers, and longer-range strike aircraft like F-111s and F-117s. Most fighter sorties were flown from relatively close to their patrols – none were flown from 1,565 nautical miles away.

These comparisons showcase that the current force mix has been optimized for short-range operations, an observation corroborated by other studies. The fighter force in particular was designed and optimized largely for operations in the central front of Europe during the Cold War. USAF fighters are less well-suited for the long-range operations that could be a feature of conflict in the western Pacific, especially if the handful of airbases well-located for fighter operations (i.e., Okinawan airbases) are neutralized by threats. Figure 9 below depicts the USAF force mix in terms of unrefueled combat radius and inventory. The length of each line, overlaid on the western Pacific, shows the unrefueled combat radius under normal weapon loads and loiter times. The width of the line shows the relative inventory of each aircraft. We see that there is an abundance of short-range aircraft. The longer-range bombers are few and far between. The picture is not likely to change with the introduction of the F-35. It will replace the numerous F-16s, but is very similar in terms of range.

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161 Bowie, The Antiaccess Threat and Theater Airbases. Also see Stillion and Orletsky, Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks.
Both Bowie (2002) and Stillion and Orletsy (1999) concluded that a robust long-range bomber force would be necessary to overcome access challenges, but those recommendations do not accord with the situation described above. Bowie notes that, historically, the USAF has allocated spending between fighters and bombers at a 2:1 ratio. However, looking forward from 2002, that ratio increased to 30:1 in favor of fighter development and procurement - to the neglect of the longer-range options that future access problems may require. The unclear status of the next-generation bomber means this ratio is unlikely to change materially in favor of longer-range combat aircraft.

**CHALLENGES IN LONG-ENDURANCE MISSIONS**

We may be tempted to think that, with the availability of aerial refueling options, the unfueled combat radius of aircraft is irrelevant - their range can be extended indefinitely. For example,

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Bowie catalogs several very long-endurance missions: 900-1,000 nm F-111 and F-117 missions in Desert Storm, a 2,400 nm F-117 mission against Panama in 1989, the 2,700 nm radius F-111 strike against Libya, and a 15 hour F-15E mission in Operation Enduring Freedom. While refueling operations do extend the combat radius of otherwise short-range fighters, long-endurance fighter operations remain problematic. Bowie emphasizes that these examples are the exception, and cannot be sustained:

Long-endurance missions are physically exhausting. A fighter cockpit gets chilly as the aircraft “cold soaks” for long periods in the low temperatures experienced at high altitude. Bladder relief must be conducted sitting down and bowel movements must be avoided. Fighter aircrews must sit on hard ejection seats and are unable to get up and move around (as in larger transport and bomber aircraft). Because of this, feet, legs, and the lower body start to go numb over time. Imagine, for example, flying on a commercial flight from the United States to the Far East in chilly air sitting on a hard uncomfortable surface and being unable to get up and stretch or go to the restroom for the entire flight... On long-distance combat missions, however, the pilot must also be mentally and physically prepared to engage in combat. Accordingly, official Air Force policy is that fighter aircrews should not exceed 12 hours per day on flight duty, which starts when aircrews report for mission briefing and ends at engine shutdown. Typically, mission preparation, briefing, taxi, and landing consumes two hours of that time (using optimistic assumptions). This results in 10 hours’ flying time for maximum mission duration. These same constraints would affect all aircraft with a fighter-style cockpit, such as the JSF and a proposed, longer-range, ground-attack variant of the F-22.¹⁶⁴

It is unreasonable to think, therefore, that the USAF could get the same sort of combat effectiveness out of fighters operating from Andersen APB as it does from fighters flying from bases located closer to the area of operations. In addition to crew fatigue, the long transit time to the Taiwan Straits would result in long mission duration (approaching the 10 hour maximum duration discussed above), a very large refueling operation, lengthier maintenance, and consequently low sortie

rates. The rest of this section will endeavor to explore just how bad the degradation to combat power would be.

**SORTIE GENERATION AT ANDERSEN AFB**

To approach the question of how much combat power can be delivered from a fully-operational Andersen AFB, this discussion will make use of a sortie generation model discussed in Appendix A. The model determines the force that can be generated from a given deployment of fighter aircraft to an airbase. The model estimates both the force generated and the requirement for fuel provided both on the ground and in the air.

We can use an airbase’s maximum-on-ground (MOG) as the upper limit on the number of aircraft that can be deployed there. At Andersen AFB this figure is 250 aircraft. If Andersen AFB were required to support the full range of operations, the base’s capacity would be split between fighter operations, bombers, tanker aircraft, mobility aircraft, and all the aircraft that give the U.S. military the situational awareness required to prosecute any operation: ISR and C2 aircraft like the E-3 (AWACS), RC-135, E-8 (JSTARS), Global Hawk, etc. Since the long-range operation of the non-fighter aircraft is less problematic (none of the problems in the inset above occur), the analysis will concern itself primarily with fighter operations. To do so, the operations of other aircraft were treated as constants – the number of fighters that Andersen AFB could support was calculated on top of the minimum number of other aircraft that would need to operate from Andersen AFB. The number of refueling aircraft required to support the fighter missions (which is quite large) is included when determining the maximum number of combat aircraft supportable. All told, if Andersen AFB had to support the full range of USAF operations in a contingency, the base could only support four to five squadrons of fighter aircraft (four squadrons if the Andersen beddown included a bomber beddown like that in Operation Desert Storm, five squadrons if the Andersen AFB beddown included no bombers).

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165 Airbase data extracted from unclassified portions of the AMC Automated Air Facility Information File.
Four squadrons, or 96 F-22s, at Andersen AFB operating at maximum operations tempo would require extensive refueling support. A single counterair mission would require at least two aerial refuelings each way, one at most 1,000 nm from Andersen AFB, and a second refueling (with less fuel taken on) just before the F-22 arrived on station. Slightly less fuel is required for the trip back (the aircraft must arrive on station with a full fuel tank, but only needs to return with sufficient reserve), but would still require two separate refuelings on the return transit. All told, the 96 F-22s at maximum combat operations tempo would require 45 full KC-135 offloads daily. Assuming that each tanker can sustain two sorties every three days, a 68-tanker beddown at Andersen AFB would be required to support the fighter operations.

Ninety-six F-22s and the tankers supporting them would require 1.6 million gallons of fuel per day at the source. Accounting for the full spectrum of USAF operations, 2.95 million gallons of fuel would be required daily. Andersen AFB has the most extensive fuel storage of any USAF facility, 66 million gallons. If full when the conflict commenced, Andersen AFB could support the maximum tempo of operations for 22 days without resupply. With unlimited resupply, Andersen AFB could support full operations tempo for three months, after which the fuel available daily would be limited to that which could be pumped from Apra Harbor. This constraint would limit Andersen AFB to 75% of full operations tempo. Of course, unlimited fuel delivery and the perfect queuing of fuel resupply is optimistic. It may also be optimistic to

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166 Drop tanks would not help significantly. They would slightly reduce the amount of fuel taken on while outbound from Andersen AFB, but would have to be jettisoned upon confronting hostile aircraft or SAMs, and so would not improve the refueling situation on the return flight. Overall, mission time would be only very slightly reduced.

167 Bowie calculates a similar fighter/tanker ratio based on a Desert Storm size deployment, where each aircraft is flying 10 hour missions. See Bowie, The Antiaccess Threat and Theater Airbases, pp. 13.

assume that none of Andersen’s fuel storage would be damaged by attacks (special operations forces or conventional attacks). Thus, an important consideration for planners (beyond the sortie generation discussion) will be the adequacy and vulnerability of the fuel infrastructure at Andersen AFB.

**Force Delivered**

To judge what force Andersen AFB could generate, we assume that each F-22 flies a defensive counter-air mission, with a 1.25 hour on-station time. A single counterair mission would consist of just under 3.5 hours transit time from Andersen AFB to the Taiwan Straits, with 1.25 hours time on station, and another 3.5 hours return flight.\(^\text{169}\) We further assume that sufficient maintenance capacity (see Appendix B), fuel, and tankers are available at Andersen AFB, and that operations are unrestricted by attacks or SOF harassment. Employing the sortie generation model discussed in Appendix A, we find that 96 F-22s at maximum operations tempo flying counter-air missions could generate 115 daily sorties, or 1.11 sorties per aircraft.

We can translate daily sorties into a continuous CAP. We do this because the long flight time from Andersen AFB prohibits a flexible defense. If the USAF needed to defend Taiwanese airspace, USAF high-value assets like ISR and AWACs aircraft, or Navy surface vessels from

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\(^\text{169}\) The F-22’s supersonic cruise does not help - it is useful in combat, but not for transiting long distances efficiently. The FW-119-PW-100 engine, while much more efficient in supersonic flight than an engine that requires full afterburners, still burns much more fuel than it does in normal cruise. Supercruise fuel flow rates are not publicly available, but an analysis of publicly-available reports suggest that supercruise fuel flow is still several times more than normal cruise fuel flow. Thus any plans to transit from Andersen AFB to the Taiwan Straits under supercruise would require several extra refueling rendezvous. These would interrupt the airplane’s high-altitude, supersonic flight profile with a required descent in altitude and a slowdown to refueling speed. The net result would be a slightly shorter mission duration, for which the price would be a several-fold increase in fuel consumed and aerial refueling aircraft required. The increased demand for fuel would result in a net drop in the steady-state number of fighters that could be maintained on station.
PLAAF attack, USAF fighters (with a 3.5 hour transit time) could not wait until warning of a PLAAF attack was received before launching. If they did, the attack would be long over before the USAF aircraft got to the area of operations. 115 daily sorties of 1.25 hours duration each means that the largest 24 hour patrol the USAF could sustain over Taiwan would be 6 F-22s.

**PLAAF Sortie Generation Potential**

In order to judge the effectiveness of the USAF air operation, we must explore what force the PLAAF could generate in opposition. Here we examine only China’s high-end fighter force of imported and indigenous Su-27s, Su-30s, and J-11s.\(^{170}\)

Determining what force China could bring to bear with its high-end fighters is similar to the calculations previously used for predicting USAF sortie rates. The main simplifying difference is that we need not consider the implications of refueling and refueling aircraft. The Flanker’s combat radius (up to 880 nm)\(^{171}\) is sufficient to cover Taiwan without being refueled, even from airbases deep within China. China’s refueling fleet is also very small, and would likely only play a ‘specialist’ role in campaigns for the foreseeable future.

In contrast to the likely USAF force posture, PLAAF aircraft would enjoy the strategic depth afforded by the basing infrastructure of a large, continental country. PLAAF aircraft operate out of a large number of airbases, including 41 military or dual-use airfields within

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\(^{170}\) While PLAAF J-10s can also be very lethal when equipped with the PL-12 air-to-air missile, we only compare against the even more capable Flankers. We will see subsequently that the Flanker numbers used in this analysis already stretch PLAAF airbase infrastructure, and adding large numbers of other aircraft to the analysis would be inappropriate. If the Flanker inventory determined below is too generous, the J-10 could be included without materially changing the findings.

The PLA AF also has a large inventory of 4th-generation fighters that would be available in a conflict. For now we will only consider China’s fleet of Su-27s, Su-30s, and J-11s (Chinese license-produced Su-27s).

2015 Inventory

We use a 2015 projected inventory. China acquired its first Su-27s from Russia in 1992. Open sources put China’s current inventory of Flankers at 271, which gives us a rate of 18 acquired or built each year. If we extrapolate this trend forward to 2015, we would expect China to have on the order of 397 Su-27s, Su-30s, and J-11s on hand.

Since China has no outstanding purchase agreements with Russia, a better method may be to assume no additional foreign purchases of Su-27s and Su-30s, and extrapolate using the number of J-11s built annually. China built 100 J-11s between 1998-2004, averaging just over 14 each year. J-11 production ceased in 2004 because the aircraft did not meet PLA requirements. Shenyang later unveiled the J-11B, with upgrades and including more indigenous components. This new variant began testing in 2006. If we conservatively assume that production resumes in 2010, and that production resumes at the same pace as the initial J-11 production, China will add around 71 Flankers to its inventory by 2015. This estimate would give the PLA AF a total inventory of 342 in 2015.

Either inventory estimate is probably more than the PLA AF would simultaneously dedicate to a Taiwan contingency, based on limitations to airbases in the region. We now turn to postulating a Flanker deployment.

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174 Ibid.
Postulated Beddown

The postulated disposition of PLAAF/PLANAF high-end aircraft is based in part on their current locations and in part on interpretations of PLA air campaign strategy. The beddown assumes that airbases currently hosting Su-27s, Su-30s, or J-11s will continue to do so in a contingency. This assumption is based on the maintenance differences between China’s higher-end aircraft and the large numbers of obsolete aircraft. Unless the PLA has made investments in maintenance capability at a large number of PLA airbases, it is likely that bases currently hosting Flankers will continue to do so. From a PLA perspective, this is not particularly problematic in terms of a Taiwan scenario - most Flanker airbases are situated within a reasonable distance of Taiwan. This is partly the result of the sales agreement with Russia, which stipulated that the aircraft could not be permanently based at locations in the proximity of China’s border with Russia.

There are 9 locations in the vicinity of Taiwan that currently base, or have based, PLA Flankers. A PLAAF fighter regiment typically comprises 24 aircraft. Most airbases have shelters sufficient for a small regiment of 24 aircraft, which indicates that the PLAAF basing concept is to disperse its operations among many airbases, each of them hosting a small aircraft regiment. For this analysis, one regiment of 24 aircraft is stationed at each airbase. This does not account for China’s entire Flanker fleet, some of which would need to deploy forward in order to be within range of Taiwan. Some Chinese aircraft would likely be positioned very close to the front, in order to intercept incoming attacks. Given the proximity of such intercept

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175 Based on Kopp, “PLAAF Airbase Infrastructure,” and a survey of news articles concerning PLAAF exercises in the vicinity of Taiwan.

176 The postulated disposition herein is consistent with scholarship on China’s likely air doctrine. The PLAAF would use a “light front, heavy rear” concept in order to limit the vulnerability of its aircraft. The “light front” aircraft would be intended to fill the interception role, since they could respond quickly to incoming enemies. The airbases in the vicinity of Taiwan may limit China to a total campaign strength of 400-500 aircraft (not including long range aircraft and force enablers). The postulated Flanker beddown above would thus account for 50-60% of this campaign strength. It is also worth noting

(Continued on the next page).
bases to an adversary, these bases would need to be relatively hardened. Airbases would also require adequate maintenance and other support capabilities. Two locations fit this description: PLA Fuzhou and PLA Changxing. These locations are both relatively close to Taiwan: 77 nautical miles and 376 nautical miles respectively. Both locations are in the most-hardened class of PLA airbases, featuring alert strips and underground hangars. Both locations also support, or have supported, the indigenous J-10, roughly comparable to the USAF F-16.177 This aircraft, while in a different class than China’s Flankers, is a step up from older, 1950s-era fighters. Its presence indicates a more robust support infrastructure. A third location not currently hosting Flankers is postulated – PLA Folou on Hainan Dao. While this location is somewhat removed from Taiwan, it is very hardened (including an underground hangar). One more regiment could join the regiment currently at PLA Hainan Dao South in order to project power into the sea approaches to China’s southern ports.

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that PLAAF doctrine calls for outnumbering the enemy 4:1 in the air, and that PLAAF planners think that the airspace in the Taiwan Strait could accommodate offensive operations of 168 aircraft at a time. You, The Armed Forces of China, pp. 129-131.

177 Kopp, "PLAAF Airbase Infrastructure."
<table>
<thead>
<tr>
<th>Airbase</th>
<th>Base Hardening Features</th>
<th>Distance to Taiwan Strait (nm)</th>
<th>Currently Hosting Flankers</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAAF Fuzhou</td>
<td>Underground Shelter</td>
<td>77</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Zhangzhou</td>
<td>Hardened Aircraft Shelters</td>
<td>112</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAN Luqiao(^{179})</td>
<td>Revetments</td>
<td>245</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Quzhou</td>
<td>Revetments</td>
<td>250</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Nanchang Xiangtang</td>
<td>Revetments</td>
<td>329</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Changxing</td>
<td>Underground shelter</td>
<td>376</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Wuhu</td>
<td>Hardened Aircraft Shelters</td>
<td>403</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Changsha Huanghua</td>
<td>Revetments</td>
<td>424</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Feidong</td>
<td>Underground shelter</td>
<td>469</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Suixi</td>
<td>Hardened Aircraft Shelters</td>
<td>541</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Polou</td>
<td>Underground shelter</td>
<td>668</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>PLAAF Hainan Dao South</td>
<td>None</td>
<td>685</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>Reserve</td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
</tbody>
</table>

Average Distance to CAP 381 nm

\(^{178}\) Base hardening features based on author’s own survey of PLA airbase infrastructure and Kopp, “People’s Liberation Army Air Force and Naval Air Arm Airbase Infrastructure.”

\(^{179}\) PLAN Luqiao is a naval aviation base and currently hosts one regiment of Su-30s and other aircraft. While PLAN aircraft will probably not be dedicated to the air superiority fight over Taiwan, we postulate here that a PLAAF regiment has been added here due to its strategic position as one of the modern airbases within range of Taiwan to efficiently generate sorties.
The table above shows the postulated contingency locations for China’s Flanker fleet. Nine airbases currently host Flankers. The other postulated contingency locations are the most hardened bases available and have indications of more-developed support infrastructure. A number are held in reserve or at bases out of range of Taiwan (see Appendix C for more details).

In order to estimate PLAAF sortie generation, we apply a sortie generation model for each PLAAF airbase. The model is similar to that used for USAF aircraft, and is detailed in Appendix C. The table below shows the contribution to a notional steady-state CAP of a regiment of Flankers (Su-27s, Su-30s, or J-11s) at each airbase. The PLA would not necessarily populate a steady-state CAP - certainly the actual campaign would be a good deal more varied and multi-faceted. However, this simplification allows us to compare Chinese sortie generation to USAF sortie generation on a daily basis, as well as explore the effect on Chinese sortie generation of attacks on these airbases.
Table 6

Sortie Rates and Airbase Contributions to Steady State CAP

<table>
<thead>
<tr>
<th>Airbase</th>
<th>Base Hardening Features</th>
<th>Distance to Taiwan Strait (nm)</th>
<th>Sortie Rate</th>
<th>Contribution to CAP (aircraft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAAF Fuzhou</td>
<td>Underground Shelter</td>
<td>77</td>
<td>3.0</td>
<td>3.73</td>
</tr>
<tr>
<td>PLAAF Zhangzhou</td>
<td>Hardened Aircraft Shelters</td>
<td>112</td>
<td>2.9</td>
<td>3.62</td>
</tr>
<tr>
<td>PLAN Luquiao</td>
<td>Revetments</td>
<td>245</td>
<td>2.6</td>
<td>3.26</td>
</tr>
<tr>
<td>PLAAF Quzhou</td>
<td>Revetments</td>
<td>250</td>
<td>2.6</td>
<td>3.24</td>
</tr>
<tr>
<td>PLAAF Nanchang</td>
<td>Revetments</td>
<td>329</td>
<td>2.4</td>
<td>3.06</td>
</tr>
<tr>
<td>PLAAF Xiantang</td>
<td>Revetments</td>
<td>376</td>
<td>2.4</td>
<td>2.96</td>
</tr>
<tr>
<td>PLAAF Changxing</td>
<td>Underground shelter</td>
<td>403</td>
<td>2.3</td>
<td>2.91</td>
</tr>
<tr>
<td>PLAAF Wuhu</td>
<td>Hardened Aircraft Shelters</td>
<td>424</td>
<td>2.3</td>
<td>2.87</td>
</tr>
<tr>
<td>PLAAF Changsha</td>
<td>Revetments</td>
<td>469</td>
<td>2.2</td>
<td>2.78</td>
</tr>
<tr>
<td>PLAAF Feidong</td>
<td>Underground shelter</td>
<td>541</td>
<td>2.1</td>
<td>2.66</td>
</tr>
<tr>
<td>PLAAF Suixi</td>
<td>Hardened Aircraft Shelters</td>
<td>668</td>
<td>2.0</td>
<td>2.46</td>
</tr>
<tr>
<td>PLAAF Folou</td>
<td>Underground shelter</td>
<td>685</td>
<td>2.0</td>
<td>2.44</td>
</tr>
<tr>
<td>PLAAF Hainan Dao South</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total CAP size: 36

These figures only include China’s most capable 4<sup>th</sup> and 4.5<sup>th</sup> generation aircraft. The indigenous J-10 fleet is not included, nor is China’s vast inventory of older obsolete fighters. The J-10 is roughly comparable to a USAF F-16 in terms of performance, and can be quite lethal when armed with the very effective PL-12 air-to-air missile. A large J-10 beddown is omitted from this analysis because the deployed inventory below approaches the maximum deployable to 4<sup>th</sup> generation-capable airfields. If the PLA began a crash program to build more
airfields or to upgrade the capabilities of numerous older airfields, the analysis would need to include a number of J-10s, and consequently, would be more ominous for USAF air superiority than it already is. A small number may find use suppressing the Taiwan Air Force, likely largely grounded by attacks on airbases. The more obsolete fighters could find use as decoys. China’s Flanker force, operating from 12 regional airbases, could sustain 690 daily sorties, or a continuous CAP of roughly 36 aircraft.

**Comparing USAF to PLAAF Sortie Generation**

A convenient and illuminating starting point is to consider the PLAAF/USAF force ratio. The figure below shows the ratio of daily sorties, or expected force ratio at any given time over the Taiwan Straits. The hypothetical sortie ratio from the same number of aircraft at Kadena AB is shown as well.

![Figure 10](image)

The curves in Figure 10 show the Flanker/F-22 ratio for aircraft operating out of bases unencumbered by attack. The ratios are steady-state ratios (or a ratio of daily potential sorties). The airpower penalty from moving operations from Kadena AB to Andersen AFB can be interpreted as the space between the Andersen curve and Kadena curve. The penalty is not quite 50%. In other words, a force at
Andersen AFB could sustain roughly half the CAP over Taiwan as an equally-sized force at Kadena AB.

Another way to interpret these curves is – at what level of degradation to operations is it more useful to operate from Andersen AFB than Kadena AB? Notwithstanding losses to aircraft, if sortie generation at Kadena AB is penalized 50% through runway cutting, attacks on fuels, or harassing special operations attacks – it is more advantageous just to operate aircraft from Andersen AFB.

Figure 12
Force Ratios for a Variety of Beddown Possibilities

The chart above shows steady-state force ratios for two beddown possibilities. 96 F-22s at Andersen AFB would give a 6:1 steady-state Flanker/F-22 ratio over the Taiwan Straits. Hypothetically, the same number of F-22s at Kadena AB would give a 3.5:1 Flanker/F-22 ratio over the Taiwan Straits.

We have seen that in an access-constrained environment, fighters may only be able to deploy to Andersen AFB. Those aircraft would be able to generate roughly one sortie a day due to the long transit times from Andersen AFB to the Taiwan Straits. In contrast, PLAAP aircraft can generate many sorties from a large number of airbases. Consequently, USAF aircraft will be severely outnumbered. The next
section discusses whether the qualitative edge of USAF aircraft and pilots can make up for the profound quantitative disadvantage.

**IMPLICATIONS OF SORTIE RATIOS**

**Introduction**

Reports from Red Flag and Northern Edge indicate that the F-22 is performing even better than expected, racking up kill ratios of 108-0 and 220-0. But it is unclear whether this means that an air operation can be sustained when outnumbered as severely as the sortie rate discussion above suggests. This section will begin with a discussion of the relative merits of the USAF F-22 and PLAAF Su-27s, Su-30s, and J-11s. We will then proceed to discuss the implications of the sortie ratios found above, and postulate a Chinese CONOP that could defeat U.S. airpower over Taiwan.

**F-22**

The F-22 is without a doubt the most capable fighter aircraft in the world today, and will be for the foreseeable future. The design incorporates several cutting edge developments: superior kinetic performance, a stealth airframe, and advanced avionics.

The F-22 is the first fighter design able to sustain supersonic flight for long periods of time. All legacy aircraft must use afterburners for the thrust required for high-speed flight (at least when carrying normal combat loads). Afterburners expend the aircraft’s fuel very, very quickly – meaning that legacy fighters can only fly at supersonic speeds for a few minutes. On the other hand, the F-22’s F-119-PW-100 engine can sustain supersonic flight without the use of afterburner, and thus with a much more reasonable fuel expenditure. This feature allows it to kinetically outperform all opponents: it can “engage, disengage and re-engage at will throughout the space/time continuum of air combat, while staying outside an opponent’s kill

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envelope."\textsuperscript{181} Further, its high speed gives its weapons a considerable boost in range and performance.

This feature alone could make the F-22 a dominant fighter aircraft. But it combines this kinetic superiority with a stealthy airframe. Unlike older-generation stealth technology, the thrust-vectoring-equipped F-22 has agility equal to (if not superior to) 4\textsuperscript{th}-generation fighter aircraft. The characteristics of the F-22’s stealth performance are not public, but is more advanced than previous generations.\textsuperscript{182} The F-22 was also designed so that the stealth materials would be more easily maintained compared to previous generations.\textsuperscript{183} While counter-stealth technology has proliferated, the F-22’s design will dramatically reduce the range at which it can be detected by opposing sensors.

The F-22’s avionics make important contributions to its edge in air-to-air combat. Though there is little public information about the F-22’s radar, we can assume the APG-77 is the most advanced and capable radar ever installed on a fighter. Future upgrades of the F-22 will incorporate side-looking radars as well. The outstanding features of the F-22 avionics suite go beyond radars and includes passive detectors and advanced networking abilities.

The F-22’s capabilities have led to its consideration for roles other than air superiority. It is currently regarded as one of the few aircraft capable of penetrating the most hostile airspace; it has consequently assumed a SEAD role and a precision strike role (with the development of the small diameter bomb allowing it to engage more targets than it could with JDAMs), among others. According the USAF Vice Chief of Staff:

\begin{itemize}
\item \textsuperscript{183} John Tirpak, “F-22 is Battle Ready,” Air Force Magazine, April 2006, pp. 46-52.
\end{itemize}
The F/A-22A is truly a multimission transformational combat aircraft. With its advanced integrated avionics providing unparalleled situational awareness, supercruise capability (the ability to fly faster than the speed of sound without afterburner) and stealth technology it is the only operational fifth-generation fighter in the world. It combines these capabilities with precision weapons to provide a joint force commander an unprecedented level of capability... The F/A-22A is not just an F/A-22A. One of the challenges we have as a result of historical traditions are labels. In addition to traditional fighter and bomber missions, the F/A-22A can conduct the kind of activities that an Airborne Early Warning and Control (AEW&C) system does, or the RC-135 surveillance aircraft does, or what an electronic attack aircraft does. What the F/A-22A brings to the equation is not just another aircraft to replace F-15s, but a multitude of capabilities for a joint force commander. It’s not just an F/A-22A it’s an F/A/B/EA/RC/E-22A.184

The F-22’s main limitation would be its inability to take on external weapons without compromising its low radar signature. In addition to 2 AIM-9 within-visual-range missiles, its internal weapons bay limits it to 6 AMRAAM beyond-visual-range air-to-air missiles, 2 JDAMs, or 8 GBU-39 small diameter bombs.185 It can carry weapons externally, but would forfeit its stealth advantage, as well as some of its kinetic advantage.

The F-22 will dominate air-to-air combat, at least in relatively equal engagements at long ranges. We will see subsequently that when outnumbered greatly, or when required to do defensive counter-air missions 1,565 nautical miles from its base, it begins to look less dominant.

Flanker

The Flanker family of fighters is second only to the F-22 in terms of performance. The aircraft was designed to be large, robust, and

powerful in classic performance terms. Flankers were built with a large internal fuel load, giving them an 880 nm unrefueled combat radius\textsuperscript{186} – more similar to deep strike aircraft like the F-111 than to USAF fighter designs.

The Flanker goes into the fight with a firepower advantage over any opponent. In addition to four R-73 Archer super-agile short-range air-to-air missiles, the Flanker variants can employ up eight to twelve R-77 Adder or R-27 Alamo BVR missiles.\textsuperscript{187} The upcoming integration of the indigenous PL-12 on PLA fighters would provide another very lethal BVR option. The BVR missiles can be exchanged for up to five very-long-range R-37 and KS-172 air-to-air missiles, with 185 and 215 nm ranges respectively. In combat, the firing doctrine is to salvo many missiles with a mix of seekers. Some Su-27 variants even have this feature built in – the pilot need only pull the trigger once and a salvo will be fired in short succession, with the aircraft computer determining the optimum timing between missiles. The seekers include active radar, heat-seeking, radar-homing, and electro-optical variants, which greatly increases the probability that one of the missiles will find its mark. Firing a large salvo with multiple missile seekers complicates the target’s ability to use countermeasures successfully (for example, the countermeasures that would defeat an active radar missile would give a radar-homing missile an easy target), and makes maneuvering out of harm’s way a more difficult proposition:

A question often asked is why are Sukhoi Flanker variants equipped to carry between eight and twelve BVR missiles? The answer is a simple one - so they can fire more than one three- or four-round BVR missile salvo during the opening phases of an engagement. In this fashion the aircraft being targeted has a difficult problem as it must jam, decoy and/or outmanoeuvre three or four tightly spaced inbound missiles. Even if we assume a mediocre per round kill probability of 30 percent, a

\textsuperscript{186} Kopp, “Sukhoi Flankers: The Shifting Balance of Regional Power.”

four round salvo still exceeds a total kill probability of 75 percent.\textsuperscript{188}

Another key feature of the design is its modularity – Flankers were designed to be upgraded, in many cases with a simple kit that can be installed by the aircraft’s normal maintenance crews.\textsuperscript{189} A key advantage to this approach is that, once a nation has procured Flankers from Russia, they have the opportunity to make sure it remains up-to-date throughout its service life.\textsuperscript{190}

Upgrade kits include the latest radars and sensors. Russian aircraft radars are comparable to U.S. radars in terms of raw power (20 kW, although Russian radars generally do not do post-processing as well). The latest Flanker radar (the NIIP Irbis-E on the Su-35 BM-class Flanker) is reportedly able to detect a .01 square meter radar cross section (RCS) target at 50 nm.\textsuperscript{191} This means that, at some range at least, Flankers with the latest radar will be able to detect stealthy aircraft.

Flankers also carry an infra-red search and track sensor (IRST), the OLS-31. This sensor can detect the thermal signatures of an aircraft in flight (at longer ranges if it is moving faster), afterburners, or a missile launch at tactically useful ranges. This affords Flanker pilots more opportunities to detect adversary aircraft – especially stealthy ones that would otherwise evade Flanker radars.\textsuperscript{192} The passive infrared sensor is limited – it does not provide the resolution that radar would and does not work under all circumstances.

\textsuperscript{188} Carlo Kopp, “The Russian Philosophy of Beyond Visual Range Air Combat.”
\textsuperscript{189} Kopp, “Sukhoi Flankers: The Shifting Balance of Regional Power.”
\textsuperscript{190} Ibid.
\textsuperscript{192} Kopp, “Sukhoi Flankers: The Shifting Balance of Regional Power.” This sensor is one reason we cannot take the results of F-22 vs F-15 dogfights as gospel. The F-15 has no sensor to fall back on besides its radar, whereas the Flankers will have at least one other viable option.
(like bad weather). However, it provides Flanker pilots another option and presents stealth aircraft with at least a risk of detection.

The Flanker is not the equal of the F-22. But the design incorporates robustness; firepower; and powerful, redundant sensors. Its modularity allows for easy upgrades and additions of cutting-edge technology. While the F-22 would almost always prevail in relatively equal engagements, numerous Flankers could be problematic for USAF operations.

**IMPACT OF SORTIE RATIOS ON THE MISSION TO PROTECT TAIWAN**

Publically available information on the F-22’s air combat capability indicates that it is vastly superior to other fighters. Analysis undertaken by British Aerospace and the British Defense Research Agency indicated that the F-22 could enjoy a 9:1 or 10:1 kill ratio against a Su-35-class fighter (an upgraded Flanker). More recent reports indicate that the exchange ratio may be as high as 30:1. Initial operational experience confirms that the F-22’s performance is as good or better than the analyses have indicated – as noted above, the F-22 has reportedly racked up kill ratios against aggressors of 220-0 and 108-0 in exercises. This record is impressive. But does this experience apply to the tactical situation F-22s might encounter over the Taiwan Straits? And if the F-22 is as invincible as initial exercises seem to show, is that enough to be decisive in the air portion of a campaign for Taiwan?

Despite the impressive results, there are still some reasons to be concerned. If we return to the much-cited 10:1 kill ratio, we may be

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195 Todd Lopez, “Raptor Excels at Establishing Air Dominance.” It is worth noting that kill ratios in dissimilar air combat training are not perfect estimators of real world performance. Exercises are intended as part simulation, part training; not pure simulation events whose purpose is to ascertain or estimate one’s own force’s performance.
tempted to think that fighting outnumbered 6:1 is not a problem. Yet a 10:1 kill ratio in relatively equal force engagements does not mean that an aircraft can fly outnumbered 10:1 – they are distinctly different measures. Fighting outnumbered to such a degree would lower that kill ratio dramatically.

For example, the Lanchester square law indicates that 10:1 superiority in equal force engagements means that fighting to a draw is only possible when the force ratio is no worse than 3.18:1. If the qualitatively superior force were outnumbered by a factor of 6, it would be annihilated, achieving only a .9:1 kill ratio in the process.196

If we use the more optimistic 30:1 kill ratio in equal force engagements, fighting to a draw may be possible if the actual force ratio were no worse than 5.5:1. The qualitatively superior force would still be annihilated if fighting outnumbered by a factor of six, racking up a 3.6:1 kill ratio in the process. These numbers are only illustrative, but they do help us think about how predicted kill ratios may and may not be interpreted. An aircraft’s supposedly superior kill ratio can degrade quickly when outnumbered drastically. And indeed, quantity does have a quality all its own.

Further, the situation facing USAF fighters is actually worse than the sortie ratios suggest. The force ratio estimate derived above represents the best case. Because PLAAF operating locations are so much closer to Taiwan area of operations, they would have tactical flexibility that the USAF cannot match. Just compare the flight times: PLAAF aircraft can take off and transit to the Taiwan area of operations in as little as 10 minutes for the closest location, 80 minutes for the most far-flung location. To do so, they would require no refueling. In contradistinction, USAF aircraft at Andersen APB would have to transit 1,565 nautical miles of ocean, giving USAF fighters at best a 3.5 hour

response time to events over Taiwan. In order to respond to a PLAAF surge, USAF fighters would require an absolute minimum of 3.5 hours warning. Even if the United States had the ISR to support such warning times, the PLA could “spoof” it by performing their preflight actions and presenting what would look like an imminent air operation, but subsequently refraining from actually conducting the operation.

This simple observation yields two important observations:

- Chinese aircraft can mass in time, with little concern that USAF fighters could respond. The long distance of Andersen AFB from the area of operations severely limits the ability of USAF to respond to PLAAF temporal concentration.

- To defend key assets, the USAF would need to populate a CAP continuously.

If Chinese planners and commanders were clever enough to take advantage of this situation, USAF aircraft would be at a serious tactical disadvantage. We have seen that the biggest sustainable 24-hour CAP would be 6 aircraft. On a continuous basis, China could put 6 fighters in the air for every USAF fighter. If the PLAAF selectively surged operations, USAF fighters would be even more outnumbered. How would USAF fighters fare in such a situation?

To structure our thinking, we will take advantage of a simple combat framework which reflects the characteristics of the F-22 and its Flanker adversary (see figure 13). This combat model will describe

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197 Supercruising, at 1000 ktas, would only moderately improve this time. While airspeed is increased, the mission would burn much more fuel, and aircraft would be required to refuel more often.

198 If, between surges, the PLA left USAF aircraft completely unmolested, USAF fighters could remain on station longer than the 1.25 hours used here. In this case, the estimate of F-22s on station could be as high as 10 at any one time. However, using this estimate would entail the strong assumption that USAF fighters would be completely unmolested during slower periods. In reality, some low-level state of harassment could be designed precisely to prevent USAF F-22s from conserving their fuel, weapons, and effort. This could be as simple as periodically sending a few decoys or spoofing the CAP with an apparent strike mission that does not materialize. The low-level harassment could occur just prior to the real raid, exhausting the fuel of aircraft on station and limiting the USAF to using fresh defenders.
three phases of an engagement: the BVR phase, which we will see is dominated by the stealth and supercruise capabilities of the F-22; the WVR phase, in which the combat conditions are much more dangerous for USAF aircraft; and the final phase of engagement, in which any Flankers not neutralized can proceed to attack their objective.

**Figure 13**

*Pictorial Combat Framework Representation*

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**BVR Phase**

For now we shall assume a best case in terms of F-22 stealth, vulnerability, and effectiveness. We shall assume that each F-22 on patrol is completely stealthy to all radar bands at BVR ranges and that Flankers can only acquire them as targets visually.\(^{199}\) The opening

\(^{199}\) This assumption could be challenged on the basis of counter-stealth technologies. There are some reasons why “stealth” may not be quite as effective as presumed. Stealth aircraft have usually been designed to be stealthy in the x-band. This is and was the predominant characteristic of scanning and tracking radars, but longer-wavelength radars can more readily detect stealth aircraft. The reasons are

(Continued on the next page).
stage of the air battle finds 36 Flankers heading towards the ISR orbits and tanker tracks on the east side of Taiwan. 6 F-22s detect the incoming aircraft and maneuver to intercept them, remaining undetected. The table below shows the ability of 6 F-22s to engage the enemy formation. The calculations assume perfectly “ordered” fire. In other words, engagements are synchronized so that each F-22 launches exactly one missile at each target.

<table>
<thead>
<tr>
<th>AMRAAM SSpk</th>
<th>Hostile Aircraft Destroyed</th>
<th>Hostile Aircraft Engaged but not Destroyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>0.5</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>0.4</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>0.3</td>
<td>11</td>
<td>25</td>
</tr>
</tbody>
</table>

F-22s in the “clean” configuration carry weapons internally to avoid a compromising radar profile, limiting the F-22 to 6 AMRAAMs and 2 AIM-9s. In the BVR fight, each F-22 can engage a maximum of 6 aircraft, with the maximum number destroyed limited by the AMRAAM’s Pk. This limits the F-22 CAP to engaging 36 aircraft. If AMRAAM performs as well as it has historically, it would have a .6 Pk. This would mean that 21 of the 36 aircraft engaged would be destroyed. A .6 Pk is probably somewhat optimistic: every documented AMRAAM kill was against a twofold – first, longer wavelengths make the geometry of the stealth aircraft ineffective. Second, they penetrate aircraft skins to a depth that makes radar absorbent materials much less effective. This may be how Serbia managed to down an F-117 in Operation Allied Force (OAF). VHF and other longer-wavelength radars have been proliferated (either new build or retrofits) especially in response to American technology. There are other technologies as well. Fortunately VHF radars cannot be employed on tactical aircraft due to their size, but ground stations may be able to pass vectors to interceptors. Based in part on Grisha Medved, “Grisha’s Stealth Pigeon Shoot,” Air Power Australia, Apr. 2008, accessible at <http://www.ausairpower.net/APA-NOTAM-230408-1.html>.

disadvantaged adversary not at all comparable to the aircraft employing the AMRAAM. Targeted aircraft were fleeing, non-maneuvering, and did not employ countermeasures. In Operation Allied Force, the Serbian Mig-29s that were shot down did not even have functioning radars. A competent adversary, maneuvering and employing countermeasures, would degrade AMRAAM performance. If the AMRAAM’s Pk is more realistic, the number of red aircraft killed would decrease accordingly. If the AMRAAM’s Pk against capable adversaries employing jamming and maneuver were cut in half to .3, only 11 targets would be expected to be destroyed.

However, an aircraft does not have to be hit to be effectively out of the fight. Evasive maneuvers are fuel-intensive. Any aircraft targeted by an F-22 which does manage to evade the AMRAAM will likely only have enough fuel to return to base. We thus assume that only the aircraft that the F-22s do not fire upon can proceed to engage their targets.

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201 Ibid.
202 If the launches were not at point-blank range (which is reasonable because the F-22s will not wish to get too close and be detected), evasive maneuvers typically begin with a quick turn to put the missile behind the targeted aircraft and full afterburner. The goal is to put as much distance as possible between the fighter and the incoming missile. If the missile was launched from far enough away (outside the “no-escape zone”), this maneuver will succeed in getting far enough away from the missile that the missile runs out of kinetic energy before it can intercept the fighter. If the pilot is not far enough away to simply outrun the missile, the target pilot will still profit from putting distance between himself and the missile. The further towards the outside of the missile’s effective range the pilot can get, the greater the likelihood that his maneuvering will bleed sufficient energy from the missile to avoid a kill. Most missiles rely on kinetic energy left over from a relatively short rocket motor burn to maneuver in the terminal intercept stage. When the missile turns sharply to follow a maneuvering target, it loses kinetic energy very rapidly. If a pilot can get to the outside of the missile’s kinetic envelope and maneuver a lot, the pilot may force the missile to lose sufficient energy so that it will be unable to successfully intercept. Throughout the entire process, the pilot will be using whatever electronic or other countermeasures he can to confuse the missile and throw it off track.
The result of a 6 on 36 engagement in which USAF fighters perfectly deconflict their targeted aircraft would be that all 36 hostile aircraft would either be destroyed or forced to disengage. However, 36 constitutes the upper limit that a 6-ship CAP, limited by internal armaments, could engage. This is a best-scenario, based on perfect deconfliction of targets and virtually invisible F-22s. Any aircraft beyond the first 36 would be unmolested, as the on-station missile magazine would be exhausted. This suggest a PLAAF CONOP as simple as sending two or more regiments of 24 aircraft each to attack USAF ISR, AWACs, and tankers. Such a raid, while not directly threatening the F-22s, would result in losses to other critical assets - making the USAF air action untenable.

WVR Phase

The F-22s on station, after expending their BVR missile load, would still have their WVR armament. However, it will only be advantageous for F-22s to engage in WVR combat against a more numerous adversary under extreme circumstances. WVR combat is something of an equalizer. The F-22’s advantages are not as decisive in WVR combat - WVR combat occurs close enough that the F-22 can be detected visually, by passive infrared sensors, or perhaps by aircraft radar. Further, the current generation of WVR missiles are particularly deadly - and WVR combat is viewed as a zero-sum game where every aircraft is liable to be killed.203 “Almost any future aircraft with a highly agile, high off-boresite missile would be a potent threat even to the F-22 in close combat.”204

Table 8 shows why engaging in WVR combat when outnumbered is seriously disadvantageous. The table depicts the results of a WVR engagement between 6 F-22s on station and 12 Su-27s (the residual

203 The current generation of WVR missiles are so deadly that their effectiveness dominates WVR combat. While the F-22 would still enjoy some advantages in WVR combat, these are not as fundamental or game-changing as its advantages in BVR combat.
204 Lorell et al., The Gray Threat: Assessing the Next-Generation European Fighters, p. 33.
aircraft of two Flanker regiments engaged by 6 F-22s). The kills shown below assumes that each F-22 and each Flanker fires two WVR air-to-air missiles, and assumes unordered fire (which best characterizes the quasi-chaotic fray of WVR combat).

| AA-11 Pk | 0.05 | 0.1 | 0.15 | 0.2 |
| Blue A/C Destroyed | 0.05 | 0.5 | 1.1 | 1.7 |

When outnumbered, a high kill ratio is only achievable if USAF missiles have a high Pk and Chinese missiles have a low Pk. PLAAF air-to-air missiles do not need to function all that well before the kill ratio is constricted considerably: if PLAAF AA-11s have a Pk as low as .2, even an AIM-9 with .8 Pk will only afford USAF fighters a 2:1 kill ratio. This observation demonstrates that, unless USAF fighters have the advantage of numerical superiority or believe there is a gross disparity in WVR missile effectiveness, engaging WVR is an unfavorable proposition. The dramatic advantages that USAF fighters, especially the F-22, enjoy in BVR combat are diminished or negated in close-range aerial combat.

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205 See Appendix D for calculation method.
Damage to USAF ISR Assets, Tankers, or Other PLAAF Objectives

So far the consideration of an air battle has been largely one-sided. USAF aircraft have attrited a PLAAF raid considerably, but their engagements are limited by the size of the on-station missile magazine. Engaging WVR will not result in a suitably high kill ratio to make it worthwhile. Thus, as long as PLAAF fighters raid with numbers sufficient to exhaust USAF fighters’ BVR missiles, some PLAAF aircraft will survive unmolested to engage their objective: high-value USAF aircraft like the E-3s, E-8s, and tankers that enable the entire operation (or ground or naval targets). Table 9 shows the expected losses to four of these aircraft from 12 surviving Flankers (out of a two-regiment raid).

Table 9
Losses to High-Value Aircraft from Leakers²⁰⁶

<table>
<thead>
<tr>
<th>Red AAM Pk</th>
<th>Flanker Warload</th>
<th>12 AA-10</th>
<th>5 R-37 or KS-172</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>3.7</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td>3.6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td>3.5</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>3.2</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>2.6</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>0.08</td>
<td>2.3</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>0.06</td>
<td>1.9</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>0.04</td>
<td>1.33</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>0.02</td>
<td>0.44</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

PLAAF Flankers could be carrying one of two warload options: standard BVR missiles or long-range counter-ISR missiles.²⁰⁷ If the

²⁰⁶ See Appendix D for calculation method.
²⁰⁷ To date, the PLAAF has not expressed any specific interest in buying Russian long-range counter-ISR and counter-AWACs air-to-air missiles. Certain writings have expressed interest in long-range air-to-air missiles in general, and such systems would certainly fit their strategic needs. Russia would almost certainly export them if China
Flankers are loaded with the longer-range air-to-air missiles, they cannot carry as many weapons, but will have an easier time finding a firing solution. At higher Pks, there is not much of a difference in the number of blue aircraft expected to be destroyed, and we might expect the advantages to longer-range engagements will outweigh the slight reduction in blue aircraft hit. At lower Pks, the more numerous BVR missiles will dominate. The likely effect of either loadout is presented above. Both warloads would be capable of destroying significant numbers of high-value aircraft unless individual PLAAF missiles are very, very ineffective.

If PLAAF fighters were to raid USAF ISR orbits or tanker tracks with even a modest-sized surge, they would overwhelm the ability of USAF F-22s to destroy them. The table above shows expected losses from a 48-aircraft raid in which 36 PLAAF aircraft are engaged, leaving 12 PLAAF fighters (those not shot down or engaged) that survive unmolested - able to engage USAF force enablers. If the raid were bigger, even more PLAAF aircraft could survive to the terminal stage - meaning more blue force enablers would be destroyed.

Further, it is not necessary that all of the PLAAF aircraft participating in such a raid be their top-of-the-line air superiority assets. The first regiment or two could be unmanned decoys or older, and somewhat expendable, aircraft - like China’s vast J-7 (Mig-21) inventory. As long as USAF aircraft shot at them, they would serve their purpose of exhausting the magazines of USAF fighters. Even if each aircraft was manned, such a mission would not necessarily be suicidal. There are indications that pilots of Russian-designed aircraft have relatively good prospects if hit by an AMRAAM. Four of five Serb Mig-29 pilots shot down in Operation Allied Force ejected and survived. This is a relatively good survival rate for pilots who are

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shot down, making the human aspect of such a raid concept at least plausible.

SENSITIVITY ANALYSIS

In this section, we will briefly examine some of the assumptions implicit in the discussion above; determine whether or not these assumptions drive the analysis; and if they do, to what extent they might lead us to draw the wrong conclusions.

A sensitivity analysis is already implicit in much of the previous discussion. In general, the previous discussion has used optimistic assumptions when it was possible to do so. Two examples are perfect deconfliction of BVR fire on the part of the USAF, and completely unordered fire by PLAAF aircraft in all phases of combat. By using optimistic assumptions, yet still finding an unfavorable outcome, we can be confident in the resulting conclusions.

In other the cases, the previous analysis has used a “point estimate” of a particularly important parameter. In these cases, we need to determine whether departing from this estimate or assumption produces a drastically different conclusion. We re-examine the effect of maintenance time, of the F-22 beddown, of the Flanker beddown, and of PLAAF maintenance capabilities.

In the previous discussion, required F-22 maintenance time was based on experience with F-15 and F-16 maintenance. Data on F-22 maintenance is still forthcoming, and in its absence, this is a reasonable substitution. However, one of the Advanced Tactical Fighter program’s criteria was that the F-22 would require less field maintenance than previous air superiority fighters.209 Anecdotal evidence indicates that this is not yet the case, but the aircraft is still being “broken in.” When it has matured operationally, we should expect to see less demand for maintenance than was modeled previously.

Previously, the turnaround time encompassed three hours of recovery actions (taxi, re-arm, refuel, etc.) and roughly nine hours of

maintenance. What would happen to the sortie generation if we relaxed the required maintenance? The figure below shows that the steady-state CAP increases with reduced maintenance requirements, but only up to a point. With reduced maintenance time, the allowable crew duty day becomes binding, and the number of crews available defines the ceiling to USAF sortie generation.

![Figure 14 Maintenance Sensitivity Analysis](image)

The previous analysis has also used a beddown of 96 F-22s. This beddown comes from a bottom-up analysis of the requirements for ISR, AWACs, tankers, and other USAF aircraft required to operate at Andersen AFB if no other options are available. However, we did see that up to 120 F-22s could be supported, for example, if Andersen AFB did not support any bombers. This number would also be the maximum that could be deployable from an F-22 buy limited to only 183 aircraft. The figures below show what level of sortie generation we could get when varying the size of the F-22 beddown. The figure on the left shows the projected Flanker/F-22 ratio from a range of F-22 beddowns. 120 F-22s could generate 142 daily sorties, for a steady-state CAP of 7.4 aircraft and a Flanker/F-22 ratio of roughly 4.5. The figure on the right combines an increased beddown with the relaxed maintenance requirements that we have already discussed.
Several assumptions also color the PLAAF side of the sortie generation discussion. First, we look at how Flanker sortie generation would be affected if they were unable to forward-deploy any aircraft. If this is the case, and only airbases that currently host Flankers contribute to the fight, the new beddown and sortie generation is shown in the table below. The feasible steady-state CAP is reduced from 36 to 27, and feasible daily sorties are reduced from 690 to 515.
Table 10
PLAAF Flanker Beddown with no Contingency Locations

<table>
<thead>
<tr>
<th>Airbase</th>
<th>Flanker Beddown</th>
<th>Distance to Taiwan Strait (nm)</th>
<th>Sortie Rate</th>
<th>Contribution to CAP (aircraft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA Fuzhou</td>
<td>0</td>
<td>77</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PLA Zhangzhou</td>
<td>24</td>
<td>112</td>
<td>2.9</td>
<td>3.62</td>
</tr>
<tr>
<td>PLAN Luquiao</td>
<td>24</td>
<td>245</td>
<td>2.6</td>
<td>3.26</td>
</tr>
<tr>
<td>PLA Quzhou</td>
<td>24</td>
<td>250</td>
<td>2.6</td>
<td>3.24</td>
</tr>
<tr>
<td>PLA Nanchang Xiantang</td>
<td>24</td>
<td>329</td>
<td>2.4</td>
<td>3.06</td>
</tr>
<tr>
<td>PLA Changxing</td>
<td>0</td>
<td>376</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PLA Wuhu</td>
<td>24</td>
<td>403</td>
<td>2.3</td>
<td>2.91</td>
</tr>
<tr>
<td>PLA Changsha Huanghua</td>
<td>24</td>
<td>424</td>
<td>2.3</td>
<td>2.87</td>
</tr>
<tr>
<td>PLA Feidong</td>
<td>24</td>
<td>469</td>
<td>2.2</td>
<td>2.78</td>
</tr>
<tr>
<td>PLA Suixi</td>
<td>24</td>
<td>541</td>
<td>2.1</td>
<td>2.66</td>
</tr>
<tr>
<td>PLA Folou</td>
<td>0</td>
<td>668</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PLA Hainan Do South</td>
<td>24</td>
<td>685</td>
<td>2.0</td>
<td>2.44</td>
</tr>
<tr>
<td><strong>Total CAP Size:</strong></td>
<td></td>
<td></td>
<td></td>
<td>27</td>
</tr>
</tbody>
</table>

Another assumption built into the PLAAF sortie generation analysis is that their required maintenance is roughly equal to the required maintenance for USAF aircraft. This assumption is not unreasonable. USAF maintainers are without equal in terms of training and quality, but the aircraft that they work on are generally more complex. Russian-designed aircraft were built for ease of field maintenance, often designed to be maintained by uneducated conscripts with few specialized tools. We would thus imagine that the poorer quality of PLAAF maintainers and equipment would be compensated by the simplicity and reduced demand of their aircraft. However, if this assumption is fallacious, the sortie rates used above will be inflated. Previously, we found that the PLAAF Flanker fleet could sustain 690 daily sorties. If we assume that PLAAF maintenance takes twice as long as USAF maintenance, their daily sorties will be reduced to 452, for a steady-state CAP of 24 aircraft.

**Sensitivity Analysis Conclusions**

The sensitivity analysis shows us that none of the assumptions drastically change the results. If USAF maintenance time is reduced to zero, and no aircraft require any maintenance whatsoever before
embarking upon another sortie, the sortie rate is still constrained by the crew ratio. This gives us a very similar USAF sortie rate if the ratio of crews to aircraft is a reasonable 1.25. A more optimistic 1.5 crews per aircraft would increase the sortie rate, but only incrementally. Likewise, a five squadron-beddown only incrementally increases the sortie ratio. When a larger beddown is combined with a drastically reduced maintenance footprint, the story changes, but this is would be a very optimistic assumption (especially since a larger F-22 beddown would increase the load on Andersen’s already-strained facilities - see Appendix B).

If we begin to adjust the PLAAF assumptions to either prohibit a large forward-deployment or handicap PLAAF maintenance, the PLAAF can generate fewer daily sorties and put together a smaller steady-state CAP. However, we have seen that the key parameter is the PLAAF ability to mass in time, and nothing in this sensitivity analysis would affect that ability. Fewer daily sorties would only mean that the PLAAF would be able to put together fewer raids, not that that those raids would necessarily be any smaller or less effective.

CONCLUSIONS

A situation in which the USAF faces a paucity of basing would severely hinder effective operations. The current USAF inventory was designed and optimized for European operations, where basing is not far from the area of operations. The Pacific theater, especially in light of anti-access threats, is very different. An Andersen AFB-only scenario would constrict the combat power the USAF could deliver in several ways: it would limit to the airbase’s MOG the number of aircraft that could be applied to a conflict, the long distance to the area of operations would curtail the sortie rate and raise the demands on refueling, and the long distance to the area of operations would asymmetrically remove USAF tactical flexibility and make response time prohibitively long.

Although USAF weapons have a pronounced qualitative edge over any possible adversary’s, it is unclear whether this edge can overcome the loss of quantitative superiority and tactical flexibility. The need to
protect expensive ISR assets and tankers would bind USAF fighters to continuous defensive counter-air patrols. Even if the F-22 performs up to expectations, its armament limits the number of aircraft it can intercept. A raid-centric concept using the sheer weight of superior numbers would allow PLAAF fighters to penetrate a USAF fighter screen and attack expensive ISR assets, the tankers that enable the entire operation, or any other important targets the USAF fighters were protecting. Decoys and obsolete aircraft would make this concept even more effective for the PLAAF. This mode of operations would be unsustainable and, unless workarounds are found, could force USAF airpower out of the western Pacific.

The next chapter explores potential alternatives.
6. DISCUSSION OF ALTERNATIVES

INTRODUCTION

We have just explored what operating at very long distances does to USAF sortie generation capability, and the sortie generation "penalty" the USAF must pay if it is to operate from Andersen AFB as opposed to Kadena AB. Around 96 fighters would fill Andersen's capacity if the USAF had to support the full spectrum of operations there. This number of fighters could sustain a 6 F-22 CAP over Taiwan, making USAF fighter outnumbered on the order of 6:1. Even if USAF F-22s are individually dominant, they may be unable to fully defend USAF force enablers against overwhelming numbers of PLAAF aircraft. Under these projected conditions, U.S. air superiority over Taiwan may not be achievable.

Thus, it is important for the USAF to develop ways to accomplish the required missions. This chapter will explore several alternatives: increasing the capacity at Andersen AFB, hardening close-in airbases, increasing the on-station missile magazine, and degrading PLAAF sortie generation through airbase attacks. To judge the effectiveness of each alternative, we will use the models previously employed.

IMPLICATIONS OF CONTINUING THE STATUS QUO

One possibility, of course, is to not do anything to improve force projection capabilities. This means allowing the status quo in terms of vulnerabilities at Kadena AB especially, but Andersen AFB as well. This approach certainly has inertia on its side, but it entails some very important implications for U.S. power in the Pacific.

If the status quo approach is taken, the United States must recognize its vulnerabilities in the Pacific and tailor its response to those vulnerabilities. For example, if there is some sort of provocation from China, the United States cannot pursue its normal course of action - which is to deploy aircraft and aircraft carriers to the western Pacific as a deterrent force. While this may have worked in 1950 and again in 1996, the approach would be less deterrent today. Recall from Cold War era nuclear deterrence studies that in order for a
deterrent to be credible, it must be survivable against a first strike.\textsuperscript{210} However, we have seen that a Chinese first strike on U.S. airbases in Okinawa or the main islands of Japan would be a devastating blow to U.S. airpower. Carrier-based airpower is also vulnerable to PLAN attack submarines and the expected modified CSS-5 anti-ship ballistic missile.\textsuperscript{211} Thus, if the United States pursues its normal course of action, what once may have been a deterrent may become a temptation. If we do nothing to enhance the survivability of our forces, we must manage crisis stability differently.

Further, failing to address the power projection challenges the USAF faces sends strong signals to allies. If the United States is not willing to make the investment to stay preeminent in the western Pacific, it would clearly concern U.S. allies in the region and around the world. Old security commitments would likely be worth less. Allies may begin to hedge. U.S. power would be seen as less credible.

The effects of decreased prestige would not be limited to the Pacific. U.S. influence could decrease worldwide. Prestige is the ability of a country to gain favorable conditions from its power without actually having to use it. U.S. prestige would certainly take a blow – the United States could find itself choosing between having to use force or settling for less. Either option is clearly undesirable.

Specific to the Pacific, failing to address power projection challenges would send a strong signal to Japan. USAF capabilities to defend Taiwan are highly correlated with USAF capabilities to defend Japan. Because of this, failing to address shortfalls in the U.S. ability to defend Taiwan would send the message to Japan that we would have problems guaranteeing their security as well. As Overholt characterizes it, the centerpiece of U.S. international security policy in Asia has been to protect Japan from China, and to protect China by

\textsuperscript{210} This was the motivation for the nuclear triad (redundancy), scrambling SAC bombers (in order to prevent them from being destroyed on the ground), and the SSBN force (they are very difficult to hunt down and destroy).

\textsuperscript{211} OSD, Military Power of the People’s Republic of China 2008, pp. 2, 23.
keeping Japan disarmed. Clearly this security paradigm would be undermined by continuing U.S. shortfalls in the western Pacific. Japan would feel less secure, and hence more likely to ramp up its own military efforts. The U.S.-Japanese alliance is already suffering from the perceived failure of the United States to stop North Korea from acquiring nuclear weapons. Further signals that the United States is not up to the job of guaranteeing its security may send Japan down its own path. What this would look like is not clear, but given the acrimonious history in the region, East Asia (and the world) would likely be more dangerous and more unstable.

Continuing the status quo therefore would present problems to U.S. power and prestige in the region and globally. In the short-term, until operational problems are fixed, the United States is better off avoiding presenting vulnerable targets (and potentially losing much of its airpower in the process). In the medium- or longer-term, it behooves the United States to consider options to address the access problem or ameliorate its consequences. These options may reduce the vulnerability of close-in airbases, increase the effectiveness of aircraft at standoff airbases, or reduce the air threat by targeting PLA operations.

**OPTION 2, HARDENING CLOSE-IN AIRBASES**

This dissertation does not explore hardening close-in airbases in depth because a concurrent research effort at RAND does. Some of the main points are summarized here.

The problem of power projection in the western Pacific is part geography and part airbase vulnerability. If there were a cost-effective way to blunt PLA anti-access capabilities, the power projection problem could be largely (but not entirely) ameliorated.

We previously considered active defenses and found the options to be lacking. One form of active defenses is interdiction – targeting and

\[\text{212 Overholt, “Disoriented: In Asia, U.S. Still Guards the Fort but Surrenders the Bank,” pp. 22-25.}\]

\[\text{213 Sheila Smith, “How Vulnerable is Japan?” talk given at RAND, 17 Apr. 2008.}\]

destroying threatening TBMs before their launch. In the context of a Taiwan scenario, this would be extremely difficult. The huge landmass and tough terrain provides ample opportunity for TELs to hide, especially if PLA air defenses relegate ISR assets to standoff orbits. The high cost of leakers calls into question the efficacy of terminal-phase interception. The PRC has an overwhelming number of TBMs. As long as they volley enough missiles somewhat simultaneously, active defenses will likely be overwhelmed. If the first round of missiles succeeds in destroying the active defenses themselves, succeeding volleys will arrive with no attrition.\(^{215}\)

Passive defenses are more promising.\(^{216}\) Hardened aircraft shelters have traditionally been the best way to protect aircraft. In the Cold War, the United States and other NATO members invested heavily in a network of hardened airbases featuring hardened aircraft shelters and dispersal parking. Hardened aircraft shelters are very effective at protecting aircraft from unguided weapons and weapons armed with submunitions. In fact, if hardened aircraft shelters eliminate the threat to aircraft from weapons armed with submunitions (guided unitary warheads are more effective against hardened shelters but can be delivered in fewer numbers), they may be a wise investment.

However, their construction would not make U.S. aircraft immune. Their effectiveness has diminished somewhat with the proliferation of guided weapons. Unfortunately the U.S. military no longer has a monopoly on guided weapons, and the reported accuracy of PLA cruise missiles and other weapons would make them effective in targeting hardened aircraft shelters. If shelters cannot take a direct hit or very near miss from a PLA DH-10 class cruise missile, the PLA will have very good options for destroying them. PLA ballistic missiles are less accurate, but if equipped with large, penetrating submunitions (with

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\(^{215}\) See discussion on pp. 71-73.

\(^{216}\) This is not to say that active defenses have no utility, only that their added utility will only be cost-effective after robust passive defenses are already in place.
much fewer per warhead than blast/fragmentation submunitions) may still be effective against hardened aircraft shelters.

Further, no hardened aircraft shelters have been designed or built for large-wingspan aircraft. Hardened aircraft shelters are typically built only for fighter-sized aircraft. The largest hardened aircraft shelters were built for U-2s at RAF Alconbury. During the Cold War, only sheltering fighters was a reasonable strategy, as fighters were forward deployed, within range of the most effective threats (namely, other fighter and strike aircraft). Larger aircraft like tankers, ISR, and AWACs were generally outside of threat range. In today’s western Pacific, however, this would not be the case. Protecting these aircraft from attack would require a new shelter design.

Figure 16
U-2 Shelter at RAF Alconbury

Advances in concrete techniques have made large-span shelters feasible. RAND has proposed a shelter design adequate to protect large-span aircraft against the unitary warheads on a CSS-6 or CSS-5. These shelters would incorporate 12 bays for large aircraft (or 36 fighters), and incorporate 12 foot thick overhead concrete and steel doors for protecting against cruise missiles. Penetrating a shelter bay would

\footnote{217 See Stillion and Caston, "Operating Airbases Under Attack."}
require two direct hits in the same spot. Such a shelter would greatly increase the costs of attacking parked aircraft. Earlier, we noted RAND work that has found that only 34 submunition warheads would be required to destroy any aircraft parked at Kadena. If 12 hardened shelters were built at Kadena AB, 1,536 weapons would be required to achieve a 90% Pk against parked aircraft.\textsuperscript{218} Such a shelter would raise the attacker’s cost to $10.7 billion from $237 million.\textsuperscript{219}

An investment in the proposed shelter design would certainly raise the costs for a Chinese antiaccess strategy based on destroying parked aircraft. Compared to the alternative of parking aircraft in the open (and having them be subsequently destroyed), it would be cost-effective. One 12-bay shelter is estimated to cost from $600m to $800m. This is expensive in absolute terms, but when one considers that the shelter could adequately protect $6.3 billion to $19.77 billion worth of aircraft,\textsuperscript{220} it is relatively cheap. Unfortunately, military construction outside the United States is very difficult to fund. In the near future, with military budgets stretched by other commitments, it looks unlikely that billions of dollars will be dedicated to hardening airbases on other countries’ soil.

While such shelters would protect aircraft, aircraft shelters alone would not be able to ensure a reasonable operations tempo from bases within range of significant numbers of ballistic missiles. Shelters like the one proposed above would make aircraft all but invulnerable, but would motivate an adversary to attack other targets: runways, fuels, maintenance shops, etc. While some vital pieces of the airbase’s sortie generation system can be hardened (fuels or maintenance) others are very difficult to harden adequately. Runways in particular present a problem. Rapid runway repair takes time, forcing operations to halt. Cratering is not necessary, simply scattering serious amounts of debris

\textsuperscript{218} Stillion and Caston, “Operating Airbases Under Attack.”

\textsuperscript{219} Estimates provided by Roger Cliff.

\textsuperscript{220} Based on the average unit procurement costs, in 2009 dollars, of 36 F-22s or 20 B-2s sheltered. Neither of these examples is implied to be a realistic or suggested use of the hypothetical shelter.
or spreading time-delay submunitions on operating surfaces would degrade operations until everything was cleared. Harassment would still be a PLA option, and could prevent flight operations without necessarily destroying aircraft.

The differences in the Israeli air campaigns against Egypt and Syria in 1967 and 1973 provide an illustration of this phenomenon. In both wars, Israel attacked enemy air forces on the ground, effectively keeping them out of the fight. In the first conflict, Israel was able to destroy hundreds of Egyptian aircraft. In the second, Syrian aircraft were sheltered, and the IAF had to attack runways and other airbase infrastructure. Syrian shelters complicated IAF efforts and protected Syrian aircraft well, but the operational effect of Israel’s attacks was the same in both instances.²²¹

Lessons from a USAF exercise in 1985 also prove instructive today. The Salty Demo exercise simulated a moderate-intensity Soviet air attack on Spangdalhem airbase in Germany. While the aircraft were sheltered and survived the attacks, airbase personnel, operating surfaces, and other equipment were hit hard. The exercise showed that redundant operating surfaces, heavy repair equipment, aircraft arresting systems, personnel survivability, and recovery procedures were vital to generating combat power.²²² Building hardened aircraft shelters can keep aircraft safe, but generating combat power demands investments in the entire system’s robustness.

This means that large investments in hardening can protect aircraft, but cannot give the USAF the kind of sanctuary it is accustomed to enjoying. Building hardened shelters would be a step in the right direction, and would certainly reduce the USAF vulnerability to a surprise attack, but itself is not enough to ensure effective power projection in the western Pacific.

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²²² Ibid.
OPTION 3, INCREASING MAXIMUM-ON-GROUND AND DEPLOYMENT TO ANDERSEN AFB

Introduction

We have seen that 96 F-22s flying from Andersen AFB are unable to secure the skies above Taiwan. Doing nothing, or maintaining the status quo capabilities and vulnerabilities, is an implicit alternative which has inertia on its side. But doing nothing to bolster USAF capabilities and reduce vulnerabilities sends a strong signal to allies and will likely degrade U.S. power and prestige in the world. Hardening close-in airbases is a step in the right direction, but cannot give the USAF the sanctuary to which it is accustomed.

One possible approach to overcome the numerical difficulties is somewhat obvious – deploy more aircraft to the theater in the event of a conflict. More aircraft, stationed at Andersen AFB or another location outside the worst level of threat, would make up for the deficiencies in fighter operations caused by long distance. But the approach would require preparations to host a number of aircraft that is currently beyond the capabilities of the base. And increasing the beddown at Andersen AFB is an inelegant solution at best. There are still problems caused by distance – an enormous refueling footprint and a large, unsheltered beddown.

Hypothetical Beddowns

We will begin examining this alternative by looking at what more aircraft would mean in terms of capability. For the time being we will set aside concerns about infrastructure and refueling. How many aircraft would the USAF need to operate from Guam to attain a more favorable force ratio over Taiwan? Recall that the status-quo or base-case ratio is six Flankers per F-22, a number that we have seen is not enough to secure Taiwan’s skies or USAF force enablers.

The number of USAF air superiority fighters required to match or come close to matching PLAAF sortie generation will be more than the F-22s currently programmed. So for this portion of the analysis, F-15Cs will be considered as well.
Table 11
Deployments Required to Meet Selected Force Ratios

<table>
<thead>
<tr>
<th>Deployment to Andersen AFB</th>
<th>F-22s Deployed</th>
<th>F-15s Deployed</th>
<th>Refueling Required (offload/day)</th>
<th>Flanker/USAF fighter ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>96</td>
<td>476</td>
<td>212 KC-135 R/T</td>
<td>6:1</td>
</tr>
<tr>
<td>Improved</td>
<td>120</td>
<td>528</td>
<td>470 KC-135 R/T</td>
<td>2:1</td>
</tr>
</tbody>
</table>

The table above shows how many USAF fighters at Andersen AFB or a base with similar range would be required to balance PLAAF sortie generation. It is quite clear that the numbers required to match PLAAF Flankers on a 1:1 basis are prohibitively large. Note also the large refueling contingent to support just over one sortie a day for each fighter. Further, achieving parity in daily sorties does not address the long flight time, which means that PLAAF aircraft can still mass in time, and USAF aircraft would be unable to respond. Of course, with greater numbers of USAF fighters, the size raid required of PLAAF aircraft would eventually become prohibitively large.

A Potential Use for Andersen Northwest Field

Andersen AFB cannot support 648 fighters, let alone the large numbers of refueling aircraft that would be required to support them. Previously we have seen that four to five squadrons of fighters would be the maximum supported by Andersen AFB. Developing a contingency plan to operate from the currently disused Northwest Field (NWF) would increase the number of aircraft that could be based at Andersen AFB.
Figure 17
Aerial View of Andersen AFB

Andersen NWF is at the northern tip of Guam. It is several miles removed from the main portion of Andersen AFB, but adjoins the munitions storage area. The runways are shorter than the main Andersen AFB – 8,500 ft. vs. 11,185 ft. and 10,558 ft – suitable for fighter operations but not heavier aircraft. A count of the parking spots and ramps shows that the surfaces could support a beddown of about 150 fighter-sized aircraft.
Looking at the 2002 aerial photo of Andersen NWF shows that a number of ramps and parking spots that are covered with jungle and growth. The main runways and taxiways look clear, but the photo was taken not too long after they were cleared with bulldozers. A photograph taken in 2008 shows a different picture, with growth encroaching the north taxiway on both sides – making it almost impassable by car, and certainly impassable to an airplane.
Making the runway surfaces useable would require them to be cleared, resurfaced, and repaired. Fortunately, the encroachment foliage does not actually crack the runway surfaces; it grows on top of the concrete in soil created by organic debris. The surfaces, even if cleared, however, show a good deal of weathering, and kick up too much debris (FOD) for fighter operations (one runway is somewhat clear and supports the occasional practice mission, but only for rough field-capable aircraft). Extensive repairs would be required: we estimate that the cost to clear and refurbish the Andersen NWF surfaces is on the order of $160m.\textsuperscript{223}

Refurbishing the airfield surfaces would bring the parking MOG up to 150, but airfield operations and fuels, among other things, would be required to generate sorties. At the moment the capability to perform these operations is precisely zero. One approach to deliver this capability when necessary, without a large up-front investment in infrastructure, would be to treat NWF as a “bare base.”

The USAF has a great deal of experience in operating at airfields with little to no infrastructure. The USAF has on hand deployable equipment to operate airfields, including flightline equipment, industrial operations sets, and Base Expeditionary Airfield Resources. Flightline equipment includes airfield lighting, arresting systems, traffic control tower, etc. Industrial operations sets include the materials needed to perform normal maintenance on aircraft. A fighter squadron typically deploys with personnel who must be housed and fed. The Base Expeditionary Airfield Resources (BEAR kits) includes all the tents, kitchens, showers, etc. necessary to support the personnel that put the airplanes in the air.

\textsuperscript{223} This estimate is based on comparison with planned repairs at Andersen AFB. $145m is budgeted to restore some of the degraded surfaces at the main airfield. The total surface area of Andersen NWF and of its parking areas is slightly larger than the surface area of the degraded areas at Andersen AFB. The estimate for Andersen NWF assumes that the repair cost per square foot of concrete would be the same or similar for both airfields. The estimate does not include infrastructure beyond the operating surfaces.
RAND has previously worked with personnel who specialize in operating expeditionary airfields, and has developed tools to assess what kind of equipment is needed to open and operate an airfield. START is a rules-based tool that estimates what equipment and personnel are required to open a base. The following table shows what assets would be needed for operations of 150 air superiority fighters. The personnel listed in the table are the personnel required beyond the personnel that would typically deploy along with the fighter squadrons. The civil engineering personnel listed below are largely the ones required to set up the rest of the equipment required to get the bare base operational.

<table>
<thead>
<tr>
<th>Category</th>
<th>Personnel</th>
<th>Equipment (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications/Air Traffic Control</td>
<td>98</td>
<td>150</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>147</td>
<td>107</td>
</tr>
<tr>
<td>Fuels</td>
<td>17</td>
<td>84</td>
</tr>
<tr>
<td>Industrial Operations</td>
<td></td>
<td>713</td>
</tr>
<tr>
<td>Flightline</td>
<td></td>
<td>2,119</td>
</tr>
<tr>
<td>BEAR (housekeeping)</td>
<td></td>
<td>1,977</td>
</tr>
<tr>
<td>Miscellaneous Vehicles</td>
<td></td>
<td>1,800</td>
</tr>
</tbody>
</table>

We can see that it would take a large amount of personnel and materiel to reach full operations tempo at Andersen NWF. The logistics footprint is quite large - on the order of 84 C-17 sorties. This might be infeasible on short notice. However, prepositioning some of the assets would reduce the amount that would need to be deployed in a contingency - especially the heavy BEAR, flightline, industrial operations, and vehicles. The lighter equipment and personnel could deploy on shorter notice, requiring only 7 C-17 flights.

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**Capability Deliver From a Combined Andersen/Andersen NWF**

A combined Andersen/Andersen NWF could host 184 fighters (184 is the entire currently programmed F-22 buy, so this beddown would be a mix of F-22s and F-15s). This force would translate into a potential CAP of 11 aircraft, sustained continuously. Our measure of effectiveness, the Flanker/USAF fighter ratio would be 3.3:1 - similar to the force that can be generated from 96 F-22s at Kadena AB. One important distinction is the long flight time that would still be necessary from the combined Andersen/Andersen NWF. The long flight time means that PLAASF aircraft could mass in time, as we have noted previously.

If the F-22s and F-15s were able to perfectly order their BVR fire, a steady-state CAP could neutralize a surge of up to 66 aircraft. This assumes no redundant targeting (i.e., one AMRAAM, one target) and that a Flanker which is engaged is either shot down or breaks off. This assumption fails if these are not the case. As we have seen, if the F-22 CAP does not perfectly queue their targets, their performance in stopping a surge would decline. In fact, if the F-22s engage targets randomly, the larger CAP would still have trouble stopping the steady-state Flankers without experiencing leakers.

**Conclusions**

Resurfacing NWF and prepositioning adequate expeditionary airfield equipment would allow the USAF to operate more aircraft from Andersen. This would substantially improve the amount of force which could be brought to bear in the airspace above Taiwan. In fact, 184 fighters at Andersen) would approximate the daily sorties that 96 F-22s at Kadena could generate.

However, this alternative entails serious drawbacks as well. First, although a combined Andersen/Andersen NWF could generate a larger number of daily sorties, the long flight time to the Taiwan area of operations still means that PLAASF aircraft could mass in time, raiding high-value assets. Note that this would be the case not just for Andersen NWF, but other possible contingency locations similarly removed from the Taiwan area of operations.
Further, the more aircraft at Andersen, the more lucrative a target it presents. Putting such a large portion of U.S. combat airpower in one location could be very risky. A large number of unsheltered aircraft would present an adversary with an important, soft target. Deploying more short-range fighter aircraft to Andersen does not really address the fundamental problem: that the western Pacific theater is not conducive to short-range aircraft.

OPTION 4, OPTIONS FOR INCREASING THE ON-STATION MISSILE MAGAZINE

Introduction

By now, it should be clear that it is very difficult to get an adequate number of fighters where they are needed. In a Taiwan scenario, F-22s operating from Andersen AFB would be unable to defend the airborne assets that support them, let alone Taiwanese airspace. Chinese aircraft could raid USAF force enablers like ISR and tankers; 6 F-22s would not have adequate armament to stop them from doing so. A Chinese CONOP that sent waves of aircraft against the USAF CAP would eventually succeed. The USAF would have a difficult time responding since the flight time from Andersen AFB to the CAP is prohibitively long. Losses of valuable force enabler aircraft could only be tolerated for so long before these aircraft would be pulled from dangerous areas altogether.

Since we note that the factor limiting the counterair performance of the F-22 is the size of its armament, this chapter considers options for increasing the total number of air-to-air missiles on station. Directed energy weapons could be a promising approach, but since the technology is in its infancy, this discussion is limited to air-to-air missiles. We begin by considering externally-loaded F-22s, move on to a hybrid option between internally-loaded F-22s and externally-loaded fighters, and conclude with an exploration of a standoff air superiority concept based around a B-1 armed with long-range air-to-air missiles.

Externally Loading F-22s

The previous analysis has assumed “clean” F-22s, with munitions carried internally only. This configuration minimizes the F-22’s
visibility, assures that it will see first and kill first, and maximizes its survivability against the SAM threat. F-22s can carry air-to-air missiles externally, but this would entail a loss of stealthiness and increase the likelihood of detection by ground-based radars, airborne early warning radars, or PLAAF fighters.

Carrying external armaments forfeits the F-22’s key advantage in air combat – stealth – to ameliorate an important weakness: the limited weapons it can carry. The effect of this trade is not necessarily obvious. While the F-22, in theory, would have more weapons to engage an enemy, forfeiting stealth decreases the F-22’s prospects for effectively employing each of these weapons. Two key assumptions drove the performance of the F-22 in our previous investigation:

- F-22s could not be engaged by enemy aircraft in BVR combat, as no other aircraft could detect them.
- F-22s ordered their BVR fire perfectly, thus using their limited warload to its maximum effect.

These assumptions are now violated.

With a compromised radar signature, the F-22 will be visible at a greater range than it would without an internal warload. This could

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225 Carlo Kopp, “Lockheed Martin/Boeing F-22 Raptor.”
allow other aircraft to detect it at tactically useful distances, meaning the F-22 with external armaments may or may not be able to engage other aircraft with impunity. In the previous investigation into its performance, we assumed that the only way it would take losses would be if it participated in WVR combat – where many of its advantages would be negated. If we consider loading the F-22 with external weapons, we must consider the possibility that it will begin taking losses in BVR combat as well.

This potential loss of immunity calls the second assumption into question. We assumed that F-22s had enough time and space to assign one air-to-air missile to each target, deconflicting targets, and avoiding redundant engagements. This would result in the most engagements and kills, and maximize the ability to attrit an attacker. However, if the F-22s can be detected and begin being engaged, perfect deconfliction of targets is probably no longer a reasonable assumption.

If the F-22s have to maneuver to avoid incoming BVR missiles, begin to take losses, and target deconfliction breaks down – their effectiveness would begin to decline. It would not need to decline too dramatically before the external weapons would actually be counterproductive and degrade its counterair performance. Let us examine an engagement where 6 F-22s, loaded with 10 AMRAAMs (instead of 6), engage two Flanker regiments. Here we relax the two assumptions used earlier, and consider the case where each F-22 is detectable, and hence, does not have the time or invulnerability to deconflict its targets. We assume that the F-22’s superior kinetic performance and avionics still give it the first shot, and that only those Flankers not initially engaged can fire back. If blue missile Pk is .6 and red missile Pk is only .1, the BVR phase of the engagement would end with only 2 of 6 F-22s surviving (12.5 Flankers expected killed, 9 scattered while evading missiles, and 26 left to proceed to WVR phase or attack other targets). The potential WVR phase would be suicidal for the remaining F-22’s, which would prudently disengage.

The vignette above represents the most extreme departure from F-22 stealth and target deconfliction, and may be more disadvantageous for the F-22 than we should reasonably expect. Still, even a partial or
less-severe departure from either condition would render external armaments counterproductive.

**Cooperative Targeting**

The superior kinetic performance of the F-22 combined with the superior situational awareness afforded by the APG-81 and supporting USAF AWACs and other ISR – points to a compromise alternative between clean F-22s and externally-loaded, aircraft. Experience in exercises shows that the F-22 can be used to enhance the effectiveness of older, legacy fighters. Here we examine an approach to utilize the greater firepower of externally-loaded aircraft, while minimizing their vulnerability. A quote from Major General Richard Lewis, discussing Raptor performance at Northern Edge, hints at what this may look like:

> When you are outnumbered on the battlefield -- the F-22 helps the F-18 and the F-15s increase their performance. It gives them more situational awareness, and allows them to get their expenditures because you can't kill all these airplanes with just the weapons aboard the F-22. It takes the F-15's and F-18's weapons. It was very successful, (in its) ability to get everybody to integrate.²²⁶

A portion of the F-22 CAP (we could substitute F-15s here) would be loaded with externally-carried air-to-air missiles to maximize the number of targets that could be engaged. These externally-loaded aircraft would need to remain in a standoff position relative to the threat because of their increased probability of being detected. The other portion of the F-22 CAP would be “clean,” carrying only internal weapons. These aircraft could operate closer to the threat relatively unobserved. The clean F-22s would detect and track targets, passing this information to the externally-loaded aircraft. Because of the F-22’s superior performance, the externally-loaded aircraft could maintain a superior kinetic profile relative to the target, and thus be able to engage from longer ranges. Once the armaments of the loaded fighters were expended, the erstwhile “spotter” F-22s could engage as well.

²²⁶ Todd Lopez, “Raptor Excels at Establishing Air Dominance.”
Two F-22s in each CAP would be “clean” and act as spotters and engagement controllers for the remaining F-22s of each steady-state CAP, which would be loaded with external AMRAAMs. This mission profile would increase the number of targets that could be engaged and maintaining the adequate low-observable profile to do so with impunity. We again assume optimal target deconfliction and that the USAF aircraft are able to fire their BVR missiles before they themselves are detected. With these assumptions in place, we can characterize the F-22 CAP’s performance in terms of the largest raid it could stop. We have seen before that this is simply the size of the on-station missile magazine. With a cooperative stealthy/non-stealthy loadout, the magazine would be increased to 52 AMRAAMs from 36 AMRAAMs.

For the PLAAF raid CONOP to be viable, they would need to dedicate more aircraft, and be prepared to take greater losses. With an artful use of decoys and expendable aircraft, the raid CONOP might still be successful, but increasing the missile magazine increases the costs of this CONOP, and at some point may render it ineffective. Unfortunately, without operating from close-in airbases, or many more standoff airbases (with many more fighters), the number above represents the largest load-out attainable. Thinking about ways to increase it further, we therefore move on to exploring a concept for standoff air superiority using a B-1.

**Standoff Air Superiority**

Loading some or all F-22s externally incrementally improves the number of targets that can be engaged. However, it still does not address the fundamental problem in the western Pacific, especially in light of China’s antiaccess capabilities, which is that the western Pacific is simply not a theater where USAF fighters can easily dominate. The long distances and lack of adequate bases suggest a different mode of operations – one which relies more on larger, longer-range aircraft from bases outside the threat. This implies a larger role for bombers armed with standoff munitions, and a lessened role for fighter/multirole aircraft. But a shift to bombers would only achieve effects on the
ground. Air superiority is still an important goal, indeed a necessary one, for the security of Taiwan.

While fighters are still clearly useful in the western Pacific, attaining air superiority and protecting key assets may require more capability than fighters alone can provide. Geography requires a platform to have long range and demand less aerial refueling. It would be advantageous if the platform could achieve more kills per sortie than a fighter. A long-range platform with more firepower would greatly complement fighter operations in the western Pacific. The alternative discussed here is a standoff air superiority platform, and is the logical extension of the cooperative engagement mode of operations discussed above. The concept is simple – modify a bomber to employ a large number of BVR missiles.

This concept would require a new, longer-range air-to-air missile and the "kill chain" to enable it to reach its target. The analysis below considers both.

Choice of Platform. In concept, any aircraft with sufficient payload capacity and range/loiter capability could be a suitable platform for standoff air superiority, but this analysis will focus on the B-1. The B-1 has several advantages in this role. First, it can fly fast. If leakers were able to get through its missile screen and past any friendly fighters in the area, it could get away from the threat quickly. Secondly, while the B-1 is not a stealthy platform, it does have features that reduce its radar cross section (reportedly to 1/50\(^{th}\) that of a B-52).\(^{228}\) At long ranges, the reduced radar cross section would be tactically useful. The B-2 might be a useful platform: it would be largely undetectable by other aircraft at long ranges, and its design gives it the ability to carry a large-aperture radar. However, its comparative advantage is penetrating enemy airspace, and it

\(^{227}\) Though effects on the ground can complement air superiority by degrading the adversary’s sortie generation. This is explored in the next section.  
will probably be required for those missions. Moreover, it lacks the speed that would enable it to outrun enemy fighters that sought to engage it. For these reasons, the B-1 is the most promising aircraft around which to build a standoff air-superiority concept.

**Comments on Feasibility.** An air-superiority bomber may seem counter-intuitive, but the concept is not as revolutionary as it may seem. The B-1R was a set of suggested upgrades proposed by Boeing in an analysis of global strike options. The B-1R would have included F-22 engines to give the B-1 (its originally intended) Mach 2.0 speed. The B-1R would have had upgraded avionics, including an AESA radar to support an air-to-air capability.\(^{229}\) The air-to-air capability was not to be its primary mission - the B-1R was still intended for long-range strike in denied environments - but the capability to conduct some air-to-air operations to support its long-range strike mission was included.

**Figure 21**
Boeing Illustration of Proposed B-1R\(^{230}\)

![B-1R Bomber](http://www.boeing.com/ids/allsystemsgo/issues/vol2/num2/images/B-1R.jpg)

What about the missiles to support a standoff air-superiority concept? The USAF currently has nothing in its inventory with ranges in the multiple hundreds of miles. But we might learn something from Russian designs. Russia has developed two missiles with very long range - the Vympel R-37 and Novator R-172. These have stated ranges of 185 miles.


miles and 247 miles respectively. The R-37 recorded a 186 mile kill in testing – a record-distance BVR kill. Both are intended to for use against high-value targets: AWACS, ISR, and tankers. Both have an active radar seeker and integrate guidance updates from the launch platform into their flight path.\textsuperscript{231} The existence of these weapons demonstrates that long-range air-to-air missiles are feasible.

\textbf{Preferred Missile Range.} What capabilities should an air-to-air missile that equip a standoff air superiority platform have? Although a fast aircraft like the B-1 would be difficult to intercept, the concept of operations would be for it to loiter well away from enemy fighters, engaging targets from a safe distance. It is not enough simply to outrange the adversaries’ longest-range missile. Let us define “outside the threat” as outside the range a Flanker can quickly dash with afterburner and launch a BVR missile. If the Flanker can use afterburners for about 7 minutes before exhausting enough fuel supplies that it is compelled to retire, at Mach 2.35 the Flanker can cover 173 nm. After coming back down to a reasonable speed, the Flanker can then employ its BVR missile, the R-77, which has a 75 nm effective range.\textsuperscript{232} The standoff air superiority B-1 must engage the Flanker and then turn


\textsuperscript{232} We have seen that other missiles have longer range but they are more suitable for engaging aircraft without high aerodynamic performance.
away from danger. A B-1 flying at roughly Mach 1 with a full fuel tank and a full complement of weapons would have a 12 nm turn radius. Aggregating these distances, a missile with a 260 nm effective range would allow an air superiority B-1 to engage fighters from outside the ranges they can pose a danger.

Figure 23
Notional Missile Range Requirement

This range would be advantageous from a detection perspective as well. The most advanced radar carried by Russian Flankers is the Irbis-E. While China does not yet employ this radar, a prudent assumption is that most current state-of-the art Russian equipment will eventually find its way into Chinese airframes or that China will eventually be able to domestically produce a system of equivalent capability. The stated range of the Irbis-E radar for a 3m² RCS target is about 190-215 nautical miles.²³³ The B-1 is not regarded as a truly stealthy aircraft, but it does have some features that reduce its RCS vis-à-vis a

²³³ Carlo Kopp, “Flanker Radars in BVR Combat.” For a 1 m² RCS target, the detection range would be approximately 153 nm.
more traditionally shaped aircraft.\textsuperscript{234} While information on the exact head-on or side B-1 RCS is not publically available, it is probably between 1m\textsuperscript{2} and 3m\textsuperscript{2}.\textsuperscript{235} Operating 260 nautical miles from threats, the B-1 would thus be outside the Irbis-E radar's detection range.

\textbf{Figure 24}
\textit{Irbis-E 187 nm Detection Radius on 3m\textsuperscript{2} RCS Target}

Modifying or borrowing from an existing missile design would be the quickest and least expensive way to develop a new, long-range air-to-air missile. There are no air-to-air missiles with sufficient range, but there are several surface-to-air missile designs that would offer potential.

\textsuperscript{235} Determined from extrapolation with B-52 RCS. The B-1 is commonly stated to have a RCS on the order of 2\% of the B-52’s RCS. Thompson, "Searching for the Next B-52."
Table 13
Selected U.S. SAMs\textsuperscript{236}

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Purpose</th>
<th>Weight</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAC-2</td>
<td>SAM</td>
<td>1,980 lbs</td>
<td>87 nm</td>
</tr>
<tr>
<td>SM-3</td>
<td>SAM</td>
<td>2,980 lbs</td>
<td>100 nm</td>
</tr>
<tr>
<td>SM-6</td>
<td>TBMD/ASAT</td>
<td></td>
<td>270 nm</td>
</tr>
</tbody>
</table>

The table above shows a selection of surface-to-air missiles that may be promising. Note that the stated range of each system is misleading. The range of a surface-to-air missile would be significantly greater if it were air-launched. A missile launched from ground begins its flight with no potential energy or kinetic energy—it must gain speed and altitude by burning its own propellant. On the other hand, an air-to-air missile starts at altitude and begins with the kinetic energy conferred by the moving launch platform. This difference is nontrivial—compare the weights of two systems with similar effective ranges: the PAC-2 and AIM-120D. The AIM-120D weighs 335 lbs, a fraction of the 1,980 lb PAC-2. However, the AIM-120D actually has a longer effective range: 98 nm vs. 87 nm.

This simple comparison shows that a PAC-2, for example, when launched from altitude from a moving aircraft, would have much greater range than the 87 nm with which it is credited when used as a surface-to-air missile. To estimate the range and weight of a BVR missile, the following sections employ a data set of BVR weapons. We now consider the structure of this estimate.

\textbf{Predicting Long-Range Air-to-Air Missile Weight.} In general, a missile system consists of three parts. There is a propulsion system, a guidance system, and a warhead. The propulsion system must vary in size with the missile range, but the guidance and warhead need not. While the author does not discount the significance of warhead design, in general, it will not necessarily be bigger with increased missile range. The weight of explosive required to do critical damage is the same whether the explosive is delivered from 2 miles away or 200 miles away.

\textsuperscript{236} Data from Jane’s Air Launched Weapons and Jane’s Naval Weapons.
The guidance system is a bit more complex. In general, terminal guidance will be about the same size. However, with very long-range missiles, terminal guidance must be augmented with datalinks to receive updates from the launching aircraft. Also, BVR missiles with active radar seekers may need to acquire the target at some distance, requiring a weightier guidance system than a WVR missile. While this suggests that guidance systems will be larger in longer range missiles, it is doubtful that it will need to grow in size at nearly the same rate as the propulsion system.

This suggests that predicting an air-to-air missile’s range with regression analysis is structurally suitable. The intercept, or fixed term, will stand in for the guidance and warhead - since these do not vary (or do not vary much) with the range of an air-to-air missile. The slope will give us insight into how the weight of the propulsion system must vary with missile range.
Visual examination shows that the pattern of missiles appears linear. One missile seems to fall well outside the pattern, however. The point in the upper left of the scatterplot seems to show amazing range performance for a very low weight. This missile is the Miniature Air-Launched Interceptor (MALI), a DARPA experiment. It is a small cruise missile look-alike which can achieve speeds of only Mach 1.15. This falls outside the paradigm of air-to-air missiles used against high-capability targets. For now, we will remove that point from the dataset. That is not to say that this missile has no lessons for us; we will return to it later.

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237 Data from Jane’s Air Launched Weapons and Carlo Kopp, “The Russian Philosophy of Beyond Visual Range Air Combat.”
238 “Miniature Air Launched Interceptor,” in Jane’s Air Launched Weapons.
Figure 26 shows a linear regression applied to the dataset of BVR missiles. If we apply the fitted regression to the case of a hypothetical 250 nm missile, we can estimate that the missile will weigh between 1,590 lbs and 2,039 lbs, with an expected value of 1,815 lbs.\textsuperscript{239} Predicting the weight of a 250 nm missile could be considered problematic since we have no data that extends close to that 250 nm range, but since we have already established the structure of the problem, we can make reasonable prediction outside the range of the data.

We can refine the prediction by including the initial operational capability or missile’s generation. Figure 27 shows that early-generation missiles tend to underperform in range for a given weight. Adding in a term to correct for this, the new prediction is 1,690 lbs (95% CI between 1,503 lbs and 1,877 lbs). This prediction is similar to

\textsuperscript{239} Note that the empirically correct way to say this is, “if we observed a number of 300 mile missiles, we would expect a distribution of weights in which 95% fell between 1590 and 2039 lbs, with the mean of that distribution at 1815 lbs.” But that does not make much sense in this prediction.
the first, but it does point out that a missile engineered today should have better performance than older systems.

**Figure 27**

BVR Missiles with Early Generations Shown

There may be other options for lowering the weight of the proposed missile, and reasons why the regression model above overpredicts the weight of a 250 nm air-to-air missile. Most of the missiles in the dataset fly a level flightpath, with the exception of the very long-range Russian missiles, the R-37 and Novator R-172. For long-range engagements a level flight path is not ideal – some kind of lofting, perhaps even a ballistic trajectory, would be optimal. This would reduce drag, and hence reduce the energy requirements for reaching a given distance. This would rule out “air-breathing” varieties like the ramjet option (discussed below) – but a more detailed tradeoff analysis could shed light on which is more advantageous. Another concept could take some lessons from the MALI, which was discarded from the dataset for being too cruise-missile-like, but that discussion will follow below once we have examined staged air-to-air missiles.

**Options for Maximizing Air-to-Air Missile Performance.** Beyond predicting the weight and range of a missile, considering the missile’s performance is important. Air-to-air missile performance is contingent on several factors. While range is clearly important, if the missile
does not have the appropriate terminal engagement performance, it will not be of military utility.

A missile intended to intercept fighter-like aircraft must be highly maneuverable in order to follow the track of the target and intercept it. The force that the missile’s structure must withstand to achieve a given turn rate scales with the square of speed. For example, a missile closing at mach 5, following a fighter flying transonic in a 4-G turn, must turn with 16 times the force − 100 Gs − in order to track the fighter. This presents challenges for designing the missile body, not to mention control surfaces (supplemented by thrust vectoring in the most advanced designs). The turn radius and associated force is a particularly difficult problem for larger air-to-air missiles.

A missile must have sufficient terminal kinetic energy to follow a maneuvering target long enough to intercept. Missiles with short-burn motors typically achieve their kinetic energy through a rocket motor that burns only for a fraction of its flight time. The motor gives the missile a high airspeed, after which the missile coasts to its intercept. Turning to track the target aircraft rapidly bleeds away kinetic energy. If a pilot is able to maneuver enough as the missile closes, he may diminish its kinetic energy to the point that it has insufficient speed to intercept the target. This tactic is more effective when the engagement occurs towards the outer envelope of the missile’s effective range. Maneuvering to bleed enough kinetic energy to defeat the missile is more challenging when the missile is fired from closer distances; kinetic energy will be higher when the missile has only recently completed its boost-phase motor burn (or if the burn is still underway).

A pilot who determines that he is sufficiently removed from the launch platform will generally “turn and burn” (flee under full afterburners) to maximize the distance the missile must cover before it intercepts him. If the pilot is fortunate, the missile was fired from outside its no-escape-zone, and the target will get far enough away that the missile runs out of energy and falls out of the sky. If the missile is fired closer, the targeted pilot will still profit from putting distance between himself and the missile. The further towards the
outside of the missile’s effective range the target gets, the greater the likelihood that the pilot’s maneuvering will bleed sufficient energy from the missile to avoid a hit.

Designers use a couple approaches to increase the kinetic performance of air-to-air missiles. These approaches are especially relevant in the consideration of a very long range missile like the one proposed here. One is an extended-burn motor. This approach deals with the rapid kinetic energy loss of a maneuvering missile by supplementing the initial kinetic energy with a sustained burn. The extended burn may be from a larger rocket motor, or a ramjet. The ramjet (used on the MBDA Meteor and Vympel R-77-PD) has the added advantage that it need not carry its oxygen with it, and thus can achieve greater range and performance for a given weight than a pure rocket. In order to function, the ramjet must be brought to a high speed by an initial rocket burn. After that, it can deliver more sustained power to the missile for increased range and better endgame performance.

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240 Carlo Kopp, “The Russian Philosophy of Beyond Visual Range Air Combat.”
A second approach is to use a two stage missile. This approach is similar to the Novator R-172, the Raytheon NCADE (in development), the SS-N-27 Sizzler anti-ship cruise missile, and a rumored Russian long-range air-to-air missile in development. The Sizzler anti-ship cruise missile is a subsonic cruise missile with a supersonic terminal stage (which greatly complicates interception by shipborne active defenses).\textsuperscript{241} The NCADE is an AMRAAM offshoot with a second stage designed for mid-course ballistic missile intercept or the anti-satellite mission. The NCADE is inappropriate as an air-to-air missile however, because the terminal stage is designed for performance exo-atmosphere and cannot track a maneuvering target. However, the systems are similar in principle, and help corroborate the conceptual utility of a two-stage design.

\textbf{Figure 30}

\textit{NCADE Schematic Shows the Stages}\textsuperscript{242}

A rumored Russian system applies the concept to the air-to-air role. Realizing that a short-burn missile can be outmaneuvered in the terminal phase, and that a very long-range missile is too large to have the maneuverability required to intercept a fighter, Vympel is reported to be working on a R-74/R-27 hybrid, possibly dubbed the R-74AE-PD. Such an arrangement would involve the R-27 in the boost phases, getting the R-74 second stage close enough to its target to engage as if it were a WVR launch.\textsuperscript{243} This approach would be very advantageous – WVR


missiles are more lethal than longer range missiles and much of this has to do with the superior performance that can be engineered into a smaller platform.

Even if this rumor is unsubstantiated, the concept is sound, and we can apply it to the problem of extreme standoff BVR kills. Any long-range weapon needs to include a consideration of terminal engagement performance – both maneuverability and kinetic energy. Sufficient kinetic energy may be provided by an extended burn rocket or a ramjet. On top of sheer kinetic energy, a missile must be suitably maneuverable to keep up with a fighter – an especially difficult problem when one considers the greater forces a fast missile must withstand to have the same turning radius as a slower airplane. This, again, is more difficult with a larger missile. Marrying a smaller terminal stage, perhaps an AIM-9 derivative, to a boost stage would be more efficient than a single-stage missile in terms of performance and the engineering required to make a long-range air-to-air missile feasible.

To consider another option for reducing a long-range air-to-air missile’s weight, we will return to the MALI, which we discarded from the dataset previously. The cruise missile-like MALI is very efficient

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244 Grisha Medved, “Grisha’s Missile Shoot-Off.”
for its effective range, but this comes at the price of performance. It does not have the kinetic energy to credibly engage a fighter. However, the concept is interesting. If this concept were applied to a first stage, which included low-observable features, the missile might be able to get somewhat close to the target undetected.

For a moment consider a notional cruise missile-like interceptor with a $0.01m^2$ RCS. A 20 kW peak power radar similar to an Irbis-E may be able to detect the interceptor at about 57 miles. If it were more stealthy, detection range would diminish, but at some point infrared systems would detect it, making further reductions in RCS ineffective. For a moment, let us assume the 57 mile figure. If a low-kinetic energy, cruise missile-like interceptor had a high-capability second stage, it could release the high-capability stage just as the target detected the threat. An AMRAAM-derivative might work well in this role. A hybrid of a cruise-missile-like first stage and a high-kinetic energy second stage might be effective in reducing overall missile weight.

**Possible Long-Range Air-to-Air Missile Payload.** The B-1 can carry from 50,000 to 75,000 lbs of ordnance, though normal loadouts tend towards the lower end of that range. For example, the B-1 carries 24 JASSMs, which puts the payload just over 50,000 lbs. By weight alone, a B-1 might be able to carry the following warloads. We present three possible missile sizes:

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245 Carlo Kopp, “Flanker Radars in Beyond Visual Range Air Combat.”

246 We discussed the AIM-9X in the second stage previously, but its range is unsuitable for the stealthy first stage strategy. Detection of the slow first stage by radar or OLS-31 is likely to occur outside of an AIM-9X effective range.
Kill Chain. The challenges of acquiring, tracking, positively identifying, and engaging a target at very long ranges are nontrivial. While a state-of-the-art radar may be able to support at least the latter part of the kill chain (all pieces except search – because the volume of airspace required to be scanned would be immense), the radar would have to be designed and implemented in the B-1, which would involve extensive costs. An easier way for a long-range missile carrier aircraft to do targeting would be to simply let other aircraft do it.

We have seen that cooperative engagement is viable given the networking capabilities of the F-22. Earlier, this paradigm was discussed in terms of stealthy F-22s assisting in targeting for other, externally-loaded fighters. A similar paradigm for standoff air superiority is attractive for several reasons: it would eliminate the need to develop an expensive new radar, the missile seeker performance would be less demanding; and fighters closer to targets would have much better situational awareness. The concept would involve the B-1 working together with fighters that were positioned closer to the target aircraft. One or more F-22s would be the logical choice. This would not "demote" the F-22 simply to being a spotter plane, however. There is no reason why the F-22 could be one that was simply out of weapons, or one which would engage after it had guided a host of long-range air-to-air missiles to target.

This concept would allow the F-22s already on station to acquire and target the enemy aircraft as they would if they were firing their own missiles. The B-1 would then be called upon to provide a certain number of missiles to a certain general area. The long flight time of a 300-mile air-to-air missile would allow ample time for an F-22 to begin

<table>
<thead>
<tr>
<th>Range, nm</th>
<th>Predicted Weight, lbs</th>
<th>Warload</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>1,351</td>
<td>44</td>
</tr>
<tr>
<td>250</td>
<td>1,690</td>
<td>36</td>
</tr>
<tr>
<td>300</td>
<td>2,030</td>
<td>30</td>
</tr>
</tbody>
</table>
relaying more specific target position and velocity to the missile via JTIDS or another suitable network architecture. Ideally, such communications would have a low probability of intercept. Given that, for at least the opening communications, the incoming missile would be behind the F-22s, this would not be too problematic. The limiting factor would be the ability to integrate and deconflict the communications of several missiles at a time.

Figure 32
Cooperative Engagement

What would be the net result of a B-1 practicing cooperative targeting? The combat situation would look much the same as it did with an all F-22 CAP. The B-1 would simply be providing more missiles for the F-22s to direct at the enemy. The net effect would be that of F-22s that “carried” dramatically more missiles, albeit without the performance penalties that would accrue from the extra weight or the stealth penalties that would accrue from externally-carried payload.247

**Feasibility.** It looks like a standoff air superiority concept based on a B-1 armed with long-range air-to-air missiles may be feasible. A long-range missile could be based on existing SAMs or could marry a shorter-range missile-based 2nd stage with a larger first stage. A ramjet concept is another option to achieve sufficient kinetic energy

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247 This would also be similar to the mixed loaded/unloaded F-22 option discussed previously. Of course, the concept described in this section would magnify the effect of that approach, if implemented.
in the terminal engagement. Another option might be a cruise-missile-like flight profile. Based on the MALI, this could result in weight savings, but would have to couple a stealthy first stage with a high-kinetic energy second stage. An analysis of existing BVR missiles shows that a 250 nm missile (not incorporating a cruise-type option) might weigh on the order of 1,690 lbs (at minimum 1,503 lbs, at most 1,877 lbs).

The most economical concept for delivering long-range kills would be integrating with downrange fighters. In this case, the fighters (preferably F-22s) would essentially direct the shots, identifying targets and calling for missiles to be delivered to a general area, upon which the F-22 would take over course updates until the missile had acquired its target. After the B-1 arsenal was exhausted, the F-22s could continue counterair engagements with their own weapons. Smooth networking would be necessary for this kind of integration. The cooperative engagement concept would likely be the most efficient, in terms of operational utility, ease of implementation, and the cost savings from foregoing very advanced radar upgrades.

**Effect of Alternatives on Operations in the Western Pacific**

The effect on operations in the western Pacific would be nontrivial. Recall the difficulties of achieving adequate fighter sorties, and the chart that depicted how severely F-22s would be outnumbered over Taiwan. We previously determined that F-22s flying from Andersen AFB would be outnumbered even by the steady-state sortie generation capabilities of PLAAP aircraft. The chart below shows how this steady-state ratio would change with standoff air superiority aircraft (all bars are scaled to a “clean” F-22 configuration, 6 AMRAAMs per missile).
We also determined previously that a key handicap of USAF counterair capabilities was the limited size of the feasible on-station missile magazine. Since PLAAF aircraft could mass in time, but USAF fighters could only engage them with the forces immediately on hand. The table below shows the number of air-to-air missiles that would be available for on-station aircraft.

Table 15
On-Station Missile Magazine

<table>
<thead>
<tr>
<th>Standoff AAM Range</th>
<th>6 F-22s</th>
<th>6 F-22s, 4 With Mixed Internal/External Arms</th>
<th>6 F-22s Plus B-1</th>
<th>6 F-22s Plus 2 B-1s</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 nm</td>
<td></td>
<td>66</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>250 nm</td>
<td>36</td>
<td>52</td>
<td>72</td>
<td>108</td>
</tr>
<tr>
<td>200 nm</td>
<td></td>
<td>80</td>
<td>124</td>
<td></td>
</tr>
</tbody>
</table>

A concerning PLAAF CONOP would be periodic mass raids against USAF force enablers. Since USAF counterair would be limited to the number of missiles on-station, sizeable numbers of PLAAF aircraft would succeed in penetrating the fighter screen and destroying important USAF assets. With perfect target deconfliction, the largest raid that could be

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248 The B-1s sorties in this example could be achievable by substituting air-to-air-centric B-1s for the bomber beddown previously attributed to Andersen AFB. Determined using the sortie generation model in Appendix A.
stopped would be one equal in numbers to the available air-to-air missiles. This is shown below in figure 34.

![Figure 34: Force Options and Raid Stopping Potential](image)

**Figure 34**

**Force Options and Raid Stopping Potential**

Conclusions

The options discussed above would increase the missile magazine available for USAF defensive counterair operations. Loading F-22s with weapons outside their internal bay would negate the F-22’s stealth, and degrade its air-to-air performance. However, a cooperative engagement option would allow some fighters to carry external weapons, with clean, stealthy F-22s assisting in targeting. An extension of this concept is an even larger, longer-range platform armed with long-range air-to-air missiles. These options would increase the USAF’s ability to deal with PLAAF raids. They would not completely remove this threat, but they would raise the costs to the PLAAF. If the missile magazine were large enough, the massed raid CONOP we investigated could get prohibitively expensive, in which case the raid threat would cease. Increasing the on-station missile magazine, moreover, could complement strikes on airbases. An enhanced counter-air capability could be very effective at “mopping up” whatever forces were not destroyed on the ground, or
persuading those forces to cease flying. We examine strikes on PLA airbases next.

OPTION 5, DEGRADING PLA SORTIE GENERATION

Introduction

We have seen the effectiveness of possible Chinese attacks on USAF airbase infrastructure, and how operating from Andersen alone would be challenging from the perspective of attaining air superiority – or defending USAF force enablers. One approach worth exploring is to attempt to do something similar to China’s airbase infrastructure. Doing so would be challenging: Chinese airbases in the theater are numerous and Chinese airbase designs give serious consideration to defense. While some of the more hardened airbases present serious challenges to an attacker – especially one only armed with standoff weapons – I find that one round of standoff attacks could degrade China’s ability to sustain high-end fighter operations by roughly half. Attacking Chinese airbase infrastructure could thus be an important piece of an air campaign associated with defending Taiwan.

To explore the issue, we will look at airbases as systems that generate sorties. The sortie-generation system consists of everything that is required to put an airplane on station: the aircraft itself, runways, fuels, maintenance, etc. When considering how best to disrupt and shut down this system, we must think in terms of the effectiveness and difficulty of disrupting the component parts. Some components of the system will be more effective to attack, some will be more difficult. The best options will be those that balance difficulty and effectiveness.

The effectiveness of attacks will depend on one’s own capabilities and the adversary’s defenses. Defenses consist of active defenses and passive defenses. Active defenses include anything that prevents a weapon from reaching its target. Passive defenses include anything that mitigates the damage caused by an attack. We now turn to a consideration of both.
Active Defenses

China’s active defenses are formidable. China has purchased 24 S-300 PMU1 and S-300 PMU2 batteries from Russia, many of which are likely deployed in the area surrounding the Taiwan Straits. Each battery comprises four TELs, along with the requisite radars and C2 equipment. Each launcher can unleash four missiles before reloading, with effective ranges from 94-122 mi against aircraft. These systems are the latest in air defense technology, with capabilities reportedly equal to if not better than U.S. Patriot systems. Moreover, their mobility provides a survivability edge. S-300 PMU1s and S-300 PMU2s can relocate rapidly, making their identification and destruction challenging. The latest generation was designed specifically to counter stealth aircraft. China has also deployed less modern, but still capable, surface-to-air missiles to the region, including SA-10s and HQ-9s. Chinese air defenses would be the most integrated and lethal system the USAF has ever faced, and would present serious risks to any fixed-wing aviation attempting to penetrate China’s airspace. Since the risk-reward probably does not support direct attacks on PLA airbases with fixed-wing aircraft, the remainder of this discussion will explore how effective standoff weapons would be.

USAF bombers carrying JASSMs or CALCMs could attack almost all PLAAF airbases within fighter range of Taiwan while remaining outside of PLA air defenses. The following figures show the areas that JASSM-ER and CALCMs could reach. JASSM-ER could cover all but a few of the PLAAF airbases in the postulated beddown used previously. The CALCM’s coverage area is shown on the right.

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252 CALCM coverage would be similar to TLAMs launched from USN submarines.
PLA Airbase Passive Defenses

PLA airbases incorporate a variety of passive defenses. The passive defenses we observe at PLA airbases include redundancy and hardening (like revetments, hardened aircraft shelters, and underground shelters). In a way, we can also consider the rough-field capabilities of some aircraft as a form of passive defense: by expanding the set of acceptable operating conditions, they reduce the impact of an attack (e.g. on runways). The following section explores the passive defenses used at PLA airbases, including examples.254

Revetments. Revetment hardening is the construction of berms, often earthen, around aircraft parking spots. This is the simplest and cheapest approach to hardening, but is also the least effective. Revetments can be effective against strafing, secondary damage from burning aircraft, and near misses. If attacking with unitary warheads, revetments would require an attacker to use at least one munition per

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253 Using open-source ranges of “over 500 nm” and 650 nm respectively. Data from Jane’s Air Launched Weapons. PLA air defense coverage from OSD, Military Power of the People’s Republic of China 2008, p. 42.

254 Base hardening features based on author’s own survey of PLA airbase infrastructure and Kopp, “People’s Liberation Army Air Force and Naval Air Arm Airbase Infrastructure.”
revetment. However, revetments are not effective against attacks using submunition warheads. It appears that the PLA is aware of revetments’ declining effectiveness as passive defenses, and is upgrading older, revetted airbases to hardened aircraft shelters.

Figure 36 shows PLA Quzhou in the Nanjing MR, home to J-7s and Su-30s. This airbase is representative of the roughly 25 percent of PLA airbase infrastructure that has simple revetment hardening. There are two fighter dispersal areas at either end of the runway, with 45 earth-berm revetments between them. Each revetment encloses parking for two fighter-sized aircraft. The base also shows a bank of 20 flow-through hangars at the northeast dispersal area. The capability of these hangars to shelter aircraft is undetermined. They may be able to shelter against small submunitions, but likely little else. A mix of underground and above-ground fuel storage is evident.

Figure 36
PLA Quzhou in the Nanjing MR
**Hardened Aircraft Shelters.** Roughly 30% of fighter bases in the Nanjing Military Region have hardened aircraft shelters. Generally, each airbase has enough hardened aircraft shelters for a small regiment of 24 aircraft (with one fighter per shelter). The designs look similar to mid-Cold War NATO “tab-v” shelters. These shelters were built to withstand near misses, with concrete thicknesses in the 3-4 foot range. Other PLAAF shelters, such as PLA Zhangzhou, are covered with earth and vegetation. The shelters often incorporate some sort of camouflage, either earth and flora or patchwork painted onto the surrounding parking ramps and taxiways.

Figure 37 shows PLA Fuzhou, with 25 hardened aircraft shelter and 10 revetments. The base is similar in layout to several revetment-only bases, and the residual revetments evident make it likely that the hardened aircraft shelters were added some time after the base was built. Camouflage is evident on the shelters and the parking areas in their vicinity. The shelters at this airbase look similar in design and size to U.S. and NATO “tab-v” HASs.

*Figure 37*

Shelters at PLA Fuzhou
PLA Zhangzhou (Figure 38) is another airbase that evidently had aircraft shelters added later in its operational life. PLA Zhangzhou shows three dispersal parking areas with fighter revetments. Two of these areas appear to have shelters added in the place of former earth-berm revetments. This airbase shows two different shelter designs. Again, most shelters look similar to U.S. and NATO “tab-v” designs, but others are larger structures covered by earth and vegetation. Note the use of camouflage to obscure parking ramps and shelters. While the camouflage is not necessarily that effective, it signals that the PLA is serious about airbase defense.

Figure 38  
Shelters at PLA Zhangzhou

PLA Zhangzhou is home to the 19th Fighter Division, an Su-27 unit, and features a 7,800 ft runway and a taxiway that could be used to launch and recover sortie if the runway were out of commission.

Underground Shelters. Several theater airbases feature very well-hardened underground shelters. These large, underground hangars are located under tens or hundreds of feet of rock, and present serious challenges to an attacker.
The aerial view of PLA Feidong (Figure 39) in the Nanjing MR shows that it is an archetypical “superhardened” airbase, similar to several others in the region. This view shows numerous hardening features which makes the base robust to attack. Note the redundant entrances into the mountain in the upper left corner of the image. These lead to a shelter under the mountain large enough for fighter aircraft.
Figure 40 shows the primary entrance, leading directly to the alert strip. The entrance is 70 feet wide, large enough to accommodate Su-27 and Su-30 aircraft. An access road leads around the south side of the mountain to the backup entrance. A concrete overhang can be seen over the entrance above. The overhang protects against attacks on the shelter doors, which are set back into the mountain. The entrance to the hangar is at a $90^\circ$ angle to the alert strip to which it connects. The $90^\circ$ turn makes getting a bomb or cruise missile into the door more difficult. If the shelter door were in-line with the alert strip, a well-guided cruise missile could potentially fly under the overhang and into the door set in to the mountain. However, the sharp right turn, and the elevation of the terrain surrounding the entrance would demand an all-but-impossible terminal maneuver.\(^{255}\) The hills directly in front

\(^{255}\) This difficulty is accentuated by the placement of the airbase. Most superhardened airbases are on the “lee” side of a mountain, or the side of the mountain on the reverse side of the enemy. This complicates ISR and forces an attacker to attacking airplane or cruise missile to approach from the other direction.
of the shelter doors prevent weapons from being able to fly straight in, under the overhang. A fighter sheltered in the facility could exit and accelerate to take-off speed in a matter of seconds.

**Figure 41**
Entrance to Underground Shelter at a Similar Airbase

![Figure 41](image1)

**Figure 42**
Secondary Underground Structure

![Figure 42](image2)
A second hill appears to have a structure inside as well. The access roads show that this shelter is not intended for aircraft. This underground structure may house fuels or other key infrastructure, providing survivability for key components of the airbase sortie-generation system. This also signals that the PLA has given significant consideration to protecting all pieces of the airbase sortie generation system.

**Theater-wide Passive Defenses.** Within 500 nautical miles of Taiwan, the PLA has 41 military or dual-use airfields encompassing most of the Nanjing MR and some of the Guangzhou MR. The hardening features at these airbases include 6 large underground hangars or shelters set into mountainsides. Bases in this area also include 97 fighter-sized hardened aircraft shelters. Most look similar to U.S. and NATO “tab-v” Cold-War era designs. PLA bases within 500 nautical miles of Taiwan incorporate as many as 400 aircraft revetments. Many of these appear unused, and some bases which were originally built with revetments have since been upgraded to hardened aircraft shelters. This supports the premise that the PLA is aware of the diminishing utility of revetments as passive defenses and is upgrading airbase passive defenses accordingly.

Most bases have one runway, but also have long, straight taxiways that could provide a minimum operating strip if the runway were out of commission. If the designers took a page from Soviet designs, the grass to the side of the runway may be reinforced with metal mesh, allowing an aircraft with a rough-field capability to operate.

PLA passive defenses go beyond the airfield itself. A key insight is that aircraft robustness is a form of passive defenses, since it increases the set of conditions under which aircraft can operate. Su-27s, Su-30s, and J-11s have many design features that allow them to operate from very rough or degraded surfaces. These features include "high-flotation tires, extremely rugged landing-gear struts, mud guards on the nosewheels, independent self-contained main gear disc-brake
cooling fans and nosewheel brakes."\textsuperscript{256,257} These features keep foreign object debris out of the engines, which are rather tolerant already, and allow the airplane to land on a variety of surfaces – including dirt, mud, snow, and ice. These features also allow rapid runway repair crews to make relatively crude repairs to craters or other damage and keep sorties going.

A look at PLA airbase infrastructure presents serious challenges to an attacker, but it also presents several opportunities. While almost all airbases incorporate some form of passive defenses, today many only include revetments. Further, not all of the revetment-only airbases are relegated to 2nd-line aircraft. PLA Quzhou and PLAN Luqiao, home to Su-27s and Su-30s, had no hardened aircraft shelters at the time of writing. This presents targeting opportunities. Further, no hardened aircraft shelters or underground shelters at PLA airbases are large enough for anything larger than fighters. None of the revetments accommodate PLAAF force enablers or other strategic assets like PLAAF and PLAN H-6 bombers, H-6U refueling aircraft, or Y-8 EW aircraft.\textsuperscript{258} Revetments are not very effective in countering modern submunition warheads, and these weapons could be employed very effectively against bases without overhead shelters. Such weapons could be very effective against parked aircraft as long as they are not airborne, relocated to better-sheltered airbases, or dispersed among many airfields.\textsuperscript{259, 260}

\textsuperscript{257} These features are indicative of the philosophical differences in U.S. and Soviet/Russian design. The U.S. tends to design airplanes with many peacetime considerations in mind: Russian aircraft design is biased towards wartime. Russian designs incorporate heavy features like the rough field capability discussed above. This makes the planes heavier, but the larger airframe compensates in terms of performance. This approach is not as efficient when conditions are good, but tends to be more robust when things go wrong. The Su-27 family demands very little in terms of infrastructure. Whether this approach or the U.S. approach is superior remains to be seen.
\textsuperscript{258} Some airbases in other regions, such as Guangzhou Shadi, have larger revetments.
\textsuperscript{259} Although economical to employ, easily detectable cruise missiles, such as TLAMs, may not be effective in destroying aircraft.

(Continued on the next page).
We now turn to looking at two options for degrading PLA sortie generation. While not exhaustive or meant to be used for actual planning purposes, the discussions below could inform general strategies and point out the main drivers of the problem. We omit investigating attacks on fuel infrastructure. While attacking an airbase’s fuels is generally a high-leverage option, very little fuel infrastructure is visible at PLA airbases. This might mean that this option would be very difficult, or it may just mean we have insufficient information to treat the option thoroughly. Below we focus on attacking operating surfaces and attacking parked aircraft.

**Degrading Operating Surfaces**

The objective of attacking operating surfaces is to make an airbase unusable to the aircraft based there. If aircraft cannot use the runway surfaces, no combat power can be generated. The approach can be useful as a complement to attacking parked aircraft by confining them to an airbase, to be destroyed in detail later.

Cratering runways is accomplished by penetrating the runway to some degree to deliver an explosive charge below the runway surface, thereby putting a large hole in the runway and damaging the surrounding concrete. The degree to which a runway is damaged, and hence the number of craters required to shut down a runway, depends on the crater size. The crater’s size, depth, and degree of damage to the surrounding concrete determines how difficult it is to repair each crater. The depth and size of the explosion determines which crater type is produced. Optimum cratering takes into account both the size of the

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If PLA command, control, and communications is somewhat competent (and not degraded by attacks), the aircraft would have plenty of warning time to scramble.

Locating aircraft outside the range that USAF standoff weapons could reach would be an effective option to protect them, but aircraft would be located to far from Taiwan to generate significant combat power. Another PLAAF option to reduce the effects of attacks would be to disperse to many airbases. Their lack of experience coordinating large maneuvers would make this an unfavorable option (the previous CONOP used only very simple coordination between regiments). But recent large-scale exercises show that the level of competence may be changing.
crater (i.e. the number of craters required to close the runway) and the type of crater (i.e. the difficulty to repair). The best crater heaves concrete slabs around the crater, and is consequently more difficult to repair.

Figure 43
Crater Types

Figure 43 shows the different crater types that can be produced, in order of the depth of the explosion. The most difficult craters to repair are those in which the surrounding concrete slabs are lifted, or heaved, by the blast. Standard craters, heave craters, and camouflets\textsuperscript{261} with heave are the most difficult types of craters to repair, and consequently the most desirable craters from an attacker’s

\textsuperscript{261} An underground detonation, the cavity of which does not entirely break the surface.
point of view. The least desirable craters from an attacker’s point of view are the pure camouflet and the scab/spall crater. The pure camouflet is the result of a blast that is too deep to damage the concrete overlay. Besides the hole where the weapon penetrated, the pure camouflet does little damage to a runway surface. Consequently, it is relatively easy to repair. The easiest crater to repair is the scab/spall crater. This crater type is created by an explosion above the runway surface. It involves only superficial, easily-repaired damage to a runway surface.\footnote{262}{Crater types taken from unclassified portions of JMEMs.}
Figure 44 shows the “cuts” — locations of craters — required to render the operating surfaces at PLA Feidong unusable. A well-designed airbase will have multiple redundant operating surfaces built into its design. Shutting down PLA Feidong’s operating surfaces would require multiple cuts. These cuts will be optimally placed at junctions, thereby damaging both a runway and a taxiway at once.

**Figure 45**
Crater Sizes and Types

**TLAM or JASSM-ER, no penetration**
- 27 weapons total
- Quick repair

**Notional penetrating TLAM or JASSM-ER**
- 17 weapons
- Medium repair

**Penetrating warhead, WDU-42 (on JASSM) or BLU-116 (on CALCM)**
- Optimum depth easily obtainable
- 14 weapons
- Difficult repair

Figure 45 graphically depicts the weapon requirements for a single runway cut, as well as what type of crater selected weapons would produce. A non-penetrating warhead, exploding on a runway surface, would be only minimally effective. Thus a TLAM or JASSM-ER would produce a shallow scab or spall crater, the easiest to repair. A notional penetrating standoff weapon (with penetrating characteristics similar to a standard Mk-83 bomb) would be more effective in terms of crater size and crater type. Specialized “bunker buster” warheads are overkill in terms of penetrating capability; they penetrate far deeper than is necessary to efficiently crater runways. However, if fused to
optimum depth, they could create a desirable camouflet/heave crater. The requirements for PLA Feidong are shown in the table below.

Table 16
Weapons Required to Shut Down one Superhardened Airbase

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Crater Type</th>
<th>Crater Diameter (ft)</th>
<th>Weapons Required</th>
<th>Difficulty of Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLAM/JASSM-ER Scab/Spall Crater</td>
<td>40</td>
<td>27</td>
<td>Quick</td>
<td></td>
</tr>
<tr>
<td>Notional Penetrating TLAM/JASSM-ER Standard Crater</td>
<td>60</td>
<td>17</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Specialized Penetrator (on CALCM or JASSM) Camouflet with Heave</td>
<td>70</td>
<td>14</td>
<td>Difficult</td>
<td></td>
</tr>
</tbody>
</table>

This examination leads to the conclusion that cratering runways is probably not the most efficient way to shut down PLA airpower. The number of weapons required to shut down a PLAAP airbase is large, especially in comparison to the number required to target that airbase’s aircraft (discussed below). In the long-run, runway cutting is only an inconvenience. Craters can be repaired (especially the less damaging ones). China would have the world’s largest construction industry at its disposal in order to do so.\(^{263}\)

Further, rough-field capable aircraft would be able to sortie anyway. Flankers were designed to operate on a variety of degraded surfaces, and could likely operate on the grass to the side of the runway. We also observe that many PLAAP airbases have purpose-built taxiways leading to the local highway infrastructure.

Attacking operating surfaces looks inefficient. It would be useful if the USAF needed to shut down operations at specific airbases at

\(^{263}\) Also note that China has given serious thought to operating degraded runways, and continuing to operate after attack. See Martin Edmonds and Michael Tsai, Taiwan’s Security and Airpower, New York: Routledge, 2003, pp. 80-82. I include camouflage, concealment, and deception - especially the liberal use of decoys, and emergency backup refueling operations which can be deployed to auxiliary airfields.
specific times, but its application more generally may not be as effective as targeting the aircraft themselves. Concrete is relatively cheap, but aircraft are expensive. In the long run, aircraft will be much more difficult to repair or replace than operating surfaces. A better approach may be to tailor attacks to destroy aircraft on the ground.

**Attacking Parked Aircraft**

China’s more-hardened airfields pose serious challenges to attackers. The rough-field abilities of Flankers make attacking runways almost futile, although this tactic could be employed against airfields with less robust aircraft. Fuels at PLA airbases are mostly underground or not evident to the author. This leaves the aircraft themselves as the most effective targets. Submunition warheads can most effectively attack area targets. Unitary warheads would be required to destroy any aircraft parked in typical hardened aircraft shelters. Underground shelters would be difficult to destroy.

**Effectiveness of Submunition Warheads Against Revetments.**

Submunition warheads can attack large area targets, and would be highest-leverage option against aircraft parked in the open or in revetments. TLAM-D would be a promising option. It contains 166 BLU-97 submunitions, each with a 29 foot lethal radius against an airplane. One TLAM-D could cover several revetments, as shown below.264

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264 See Appendix E for method.
Effectiveness of Standoff Weapons Against Hardened Aircraft Shelters. Destroying a hardened structure is a matter of applying sufficient overpressure to the concrete structure in order to cause a lethal failure in its structural integrity. For most targets we encounter, the overpressure required is commensurate with a near-miss by common weapons in the USAF inventory. This approach is consistent with targets like typical hardened aircraft shelters. Before the advent of precision warheads, destroying a sheltered aircraft would have been very, very difficult. Precision guidance allows the delivery of warheads close to their aimpoint, usually close enough to destroy aircraft shelters. The following figure shows the lethal radius of a CALCM superimposed on the schematic of a hardened aircraft shelter. The table shows the probability of a kill for a variety of standoff weapons.
U.S. standoff weapons, because of their precision, would be very lethal against hardened aircraft shelters if they reach their intended target. The regional active defenses are quite formidable, with the S-300 PMU1 and S-300 PMU2 reported to have a Pk against a cruise missile of .4-.85,\textsuperscript{266} clearly high enough to significantly degrade a large scale attack by standoff weapons. It is likely, however, that the abilities of the acquisition, tracking, and fire control radars are the limiting factor in engaging cruise missiles. The ability to do so, as well as the low-altitude coverage of these radars, is unknown to the author. Regardless, the attrition of U.S. standoff weapons would be minimized by executing a large standoff attack at once.

\textsuperscript{265} See Appendix E for calculation method. Assumes successful weapon employment and fusing.

\textsuperscript{266} Carlo Kopp, “Almaz S-300/PT/PS/PMU/PMU-1/PMU-2, Almaz S-400 Triumf, Almaz S-400 Samoderzhets.”
Since the likely performance of Chinese air defenses is unknown, we approach the attrition of standoff weapons parametrically. The table below shows the probability of destroying a hardened aircraft shelter with one or two CALCMs for a range of degradation caused by air defenses:

<table>
<thead>
<tr>
<th>Attrition</th>
<th>Overpressure Kill</th>
<th>Direct Hit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One Weapon</td>
<td>Two Weapons</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>.1</td>
<td>.9</td>
<td>.99</td>
</tr>
<tr>
<td>.2</td>
<td>.8</td>
<td>.96</td>
</tr>
<tr>
<td>.3</td>
<td>.7</td>
<td>.91</td>
</tr>
<tr>
<td>.4</td>
<td>.6</td>
<td>.84</td>
</tr>
<tr>
<td>.5</td>
<td>.5</td>
<td>.75</td>
</tr>
</tbody>
</table>

It is immediately evident that, at current levels of weapon accuracy, attrition due to air defenses would account for virtually all failed attacks on hardened aircraft shelters. This is true whether using the overpressure criterion or the direct hit criterion. However, even with relatively high rates of attrition, high Pks can still be achieved by targeting shelters with two standoff weapons. As long as air defenses are not too effective, or as long as air defenses can be overwhelmed with large numbers of weapons, standoff munitions could be very effective in attacks against aircraft parked in hardened aircraft shelters.

**Challenges Imposed by Underground Shelters.** We have seen that U.S. standoff weapons could be very effective if used against aircraft parked in revetments or hardened aircraft shelters. The more developed bases’ underground shelters impose a completely different kind of problem, with aircraft parked under tens or hundreds of feet of rock. We now turn to an analogy from Operation Allied Force (OAF), which gives us some insight into the problem.

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267 See Appendix E for calculation method.
There is one example of air attack on a "superhardened" airfield along the lines of PLAAF Feidong or PLAN Yiwu. During OAF, the USAF repeatedly attacked Slatina AB near Pristina:

On April 28, a large, coordinated attack was launched against the Serb military airfield at Podgorica, with 30 munitions employed against such targets as hardened shelters, POL facilities, radar sites, and aircraft and helicopters parked in revetments. During that attack, a 4,700-lb GBU-28 "bunker-buster" was dropped for the first time in Allied Force by an F-15E on an underground aircraft and equipment storage hangar at the Pristina airfield. (By that point in the air war, F-15Es had begun flying seven-and-a-half-hour missions into Serbia directly from RAF Lakenheath in England.) Having been repeatedly attacked before with less destructive munitions, that buried hangar and the remaining aircraft, munitions, and supplies kept in it were thought to have been taken out once and for all by this weapon, an assessment which later proved false.268

At the end of hostilities, the rubble was cleared from in front of the underground hangar doors. The Mig-21s in the facility pushed out, took off, and flew to a location in Serbia.269,270 The attack described above did not succeed in destroying the sheltered aircraft.

The following figures show the airbase after the attacks. The first photograph shows that USAF attacks did succeed in puncturing the overhang outside the shelter door. This attack did place sufficient rubble on the taxiway to pin the aircraft in the shelter, but did little lasting structural damage. The second photograph shows the underground shelter before and after the GBU-28 strike. The strike did not succeed in damaging any aircraft parked inside the shelter.

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270 The design of the shelter could not accommodate twin-tail aircraft. Thus, Serbia’s more modern and valuable Mig-29s were not housed inside.
We can draw some lessons-learned from the experience of OAF. Strikes against a very hardened airfield with anything but the most advanced, purpose-built penetrating warheads are not likely to achieve lasting effects. Cruise missile or other strikes would only be minimally effective - they may succeed in pinning aircraft in the tunnel

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for a time, but a determined adversary would clear up rubble and repair craters to keep aircraft flying.

On the other hand, the sortie rate that an adversary could achieve from a “superhardened” facility is likely very poor. Outside of the PRC, some underground hangars are meant as cold-storage – they are not really envisioned to generate sorties, only to protect aircraft until threats have diminished. PLA superhardened facilities do not appear to fit into this paradigm. The alert strips leading directly from the hangar entrance suggests a more active role, as does the size of the ventilation infrastructure above the underground shelter. The alert strip and ventilation indicates that the shelters are designed to allow aircraft to perform all pre-flight actions while inside the underground shelter, “allowing the fighter to roll out of the tunnel, line up, open the throttles and take off quickly.”272 However, performing these actions while inside a tunnel is probably not as efficient as normal airfield operations, especially if preflight actions can only be accomplished for one aircraft at a time.

Aircraft parked in underground hangars at the handful of superhardened PLA facilities would be very difficult to destroy, and certainly require sorties capable of employing GBU-28 or better penetrating warheads. This would demand putting fixed-wing aviation directly above these targets – and in the air defense environment that China will present, the risk-reward ratio of doing so would just not be worth it. Less effective (standoff) attacks could pin these aircraft in shelters temporarily, but only until the base mobilized enough labor to clear the rubble and perform rudimentary (if any) runway repairs. Specialized weapons like fuel air explosives could be used to create large overpressures over large areas. This would be useful for damaging ventilation infrastructure: valves, intakes, etc. Such attacks could force certain actions – like running aircraft engines – to occur outside the tunnel shelter. This would further degrade the efficiency of

272 Kopp, “People’s Liberation Army Air Force and Naval Air Arm Airbase Infrastructure.”
operating out of a tunnel. The extent that electromagnetic weapons could penetrate into underground shelters and the extent that PLA airbases are electromagnetically hardened is unknown. If those unknowns proved to be favorable, electromagnetic options could be useful in degrading or destroying the electronics of sheltered aircraft.

If accessible, fuels and other critical infrastructure would be high-leverage targets. High-value aircraft parked in the open would be lucrative targeting opportunities as well. Destroying H-6s on the ground would lessen the cruise missile threat to critical USAF airbases, particularly Andersen AFB. Destroying PLA AF ISR would degrade their situational awareness, lessening the ability of PLA AF aircraft to engage efficiently. And destroying EW aircraft, like the Y-8, would remove another force multiplier. All these aircraft are unsheltered. Further, many of PLA AFs high-end fighters are not at facilities hardened other than by revetments. If surprise could be achieved, and these aircraft caught on the ground, submunition warheads would be very effective.

**Effects of Proposed Attacks**

We now turn to an exploration of some limited standoff attacks on the PLA airbases most likely to host high-capability fighter aircraft. Since Chinese airspace would be strongly defended, the attack regime here will consider only standoff weapons. We review the steady-state CAP that Chinese aircraft could theoretically support, and the reduction of this steady-state CAP that successive attacks could produce. We will see that some limited attacks would be successful in degrading – but not completely stopping the sortie generation of Chinese high-capability fighter aircraft.

The table below reproduces the contribution to a notional steady-state CAP of a regiment of Flankers (Su-27s, Su-30s, or J-11s) at each of the bases listed in table 5. As before, the following posture shows 12 of 14 high-end fighter regiments dedicated to a Taiwan contingency, with 2 held in reserve. The PLA would not necessarily maintain a constant number of aircraft on station – certainly the actual campaign would be a good deal more varied and multi-faceted. However, this
simplification allows us to explore the effect on Chinese sortie generation of attacks on these airbases.

Table 19
PLAAF Airbase Contributions to Sortie Generation

<table>
<thead>
<tr>
<th>Airbase</th>
<th>Base Hardening Features</th>
<th>Distance to Taiwan Strait (nm)</th>
<th>Contribution to CAP (aircraft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA Fuzhou</td>
<td>Underground Shelter</td>
<td>77</td>
<td>3.73</td>
</tr>
<tr>
<td>PLA Zhangzhou</td>
<td>Hardened Aircraft Shelters</td>
<td>112</td>
<td>3.62</td>
</tr>
<tr>
<td>PLAN Luquiao</td>
<td>Revetments</td>
<td>245</td>
<td>3.26</td>
</tr>
<tr>
<td>PLA Quzhou</td>
<td>Revetments</td>
<td>250</td>
<td>3.24</td>
</tr>
<tr>
<td>PLA Nanchang Xiantang</td>
<td>Revetments</td>
<td>329</td>
<td>3.06</td>
</tr>
<tr>
<td>PLA Changxing</td>
<td>Underground shelter</td>
<td>376</td>
<td>2.96</td>
</tr>
<tr>
<td>PLA Wuhu</td>
<td>Hardened Aircraft Shelters</td>
<td>403</td>
<td>2.91</td>
</tr>
<tr>
<td>PLA Changsha Huanghua</td>
<td>Revetments</td>
<td>424</td>
<td>2.87</td>
</tr>
<tr>
<td>PLA Feidong</td>
<td>Underground shelter</td>
<td>469</td>
<td>2.78</td>
</tr>
<tr>
<td>PLA Suixi</td>
<td>Hardened Aircraft Shelters</td>
<td>541</td>
<td>2.66</td>
</tr>
<tr>
<td>PLA Folou</td>
<td>Underground shelter</td>
<td>668</td>
<td>2.46</td>
</tr>
<tr>
<td>PLA Hainan Do South</td>
<td>None</td>
<td>685</td>
<td>2.44</td>
</tr>
</tbody>
</table>

Total CAP size: 36

The highest priority targets would be those with the highest payoff defined in terms of CAP reduction per weapon expended. Among similar bases, bases with the highest contribution to a CAP (i.e., bases close where a high sortie rate is expected) would be priorities. Considering different types of airbases, revetted bases would be the priority since one standoff weapon could target several revetments
simultaneously. Bases with hardened aircraft shelters would require one or more standoff weapons per shelter in order to destroy the aircraft inside – this would entail less effect per weapon, and consequently attacking these bases would be a lower priority. The attack option outlined here would not explicitly target aircraft at bases with underground shelters. We have already explored the serious difficulties inherent in attacking “superhardened” PLA airbases. The best approach may be to force units at these bases to operate from within the underground shelter and experience the inefficiencies and slower sortie generation associated with that approach. Here we assume that once large-scale attacks commence, all operations will move to the most secure facilities on each airbase – be they revetments, hardened aircraft shelters, or an underground shelter.

The following figure shows the calculated reduction in PLAAP/PLANAP ability to sustain a CAP over the Taiwan area of operations. The analysis considers reductions in CAP sustainability due to aircraft losses on the ground.\textsuperscript{273,274} As the number of standoff

\textsuperscript{273} Fouling fuel and cratering runways are potentially useful activities – but the effects will be temporary. If a base is completely devastated, but the aircraft are not destroyed, they can relocate elsewhere. China has many airfields, and though most will not have the maintenance infrastructure suitable for efficiently supporting their higher-end aircraft, they would likely relocate to an untouched airfield. One paradigm for airfield attack is cratering the runways to restrict aircraft to an airbase, then destroying those aircraft through repeated attacks on shelters. This paradigm is probably not viable against China – their aircraft can taxi and take off on a variety of surfaces. Many airbases have purpose-built aircraft-sized connections to off-base roadway infrastructure. Destroying aircraft is the only sure, permanent way to destroy an air force – at least until more aircraft can be built or bought.

\textsuperscript{274} The expected number of aircraft destroyed here is derived from the probability that the standoff munition survives to engage its target multiplied by the probability that it hits its target multiplied by the fraction of the time that an aircraft is in a parking space or shelter. The amount of time that an aircraft is parked will be the total time it spends not flying or taxiing. For example, for 26 CALCMs attacking the 26 HAS at PLA Suixi, assuming that 20% of the weapons are intercepted by air defenses, the calculation is as follows: \textit{Aircraft destroyed} = \textit{(24 aircraft)}(.8 survival rate)(P_k=1)(60\% of aircraft parked in shelter at any given time) = 11.5 aircraft expected to be destroyed.
munitions expended increases, we notice that there are diminishing returns to attacks on airbases. The initial reduction – from a CAP of 36 to roughly 30 – is the result of forcing Chinese bases to use presumably less efficient alert procedures at superhardened airbases.\textsuperscript{275} The next steepest reductions are the result of attacking revetment-only airbases with one round of submunition weapons (TLAM-D). The next steepest region of PLAAF/PLANAF capability reduction is the result of a second wave of submunition weapons directed against the same targets. The flatter portion of the curve shows the result of the first and second waves of standoff weapons with unitary warheads attacking hardened aircraft shelters.

\textsuperscript{275} Here we assume that operations from underground hangars are only 50\% as efficient as operating from shelters, revetments, or with aircraft parked and maintained in bays or in the open.
Figure 50 shows that an attack on high-end fighter aircraft at a limited number of bases could significantly reduce the magnitude of the fighter threat to USAF aircraft. The effects depicted in figure 50 are based on current PLA airbase hardening features. We previously noted that the PLA appears to be upgrading older, revetted airbases to feature hardened aircraft shelters. See figure 51 for the effect of attacks if all revetment bases are upgraded to include 24 hardened aircraft shelters. The full attacks pictured above, with a 20% munition intercept rate, would likely destroy 115 Flankers (of the 288 Flankers we postulate are in theater and reduce the ability to sustain a CAP by 55%. If all PLAAF airbases are upgraded to include hardened shelters,

\[\text{Steady-State Taiwan CAP}\]

\[\text{Intercept rate=.2} \quad \text{Intercept rate = .4}\]

\[\text{Standoff Weapons Required}\]

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\[\text{PLAAF Su-27, Su-30, J-11 Cap Reduction}\]

\[\text{Intercept rate} = 0.2 \quad \text{Intercept rate} = 0.4\]

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\[\text{Again using PLA Suixi as an example, the new, post-attack sortie rate and contribution to CAP is then calculated using 12.5 aircraft (24 original - 11.5 destroyed) operating from PLA Suixi.}\]
achieving the same effects would take roughly double the weapons. These attacks should be concentrated on airbases that are known to host or are likely to host China’s most advanced fighter aircraft. They should be prioritized to attack the “softest” bases first. It may be too difficult to effectively attack the aircraft at the hardest bases – those with underground shelters, but simply forcing those aircraft to use the shelters for normal operations would induce an efficiency penalty.

**Figure 51**

*Effects of Standoff Attacks on PLAAF/PLANAF ability to sustain Notional CAP – Upgraded HAS*

The above conclusions depend on several assumptions

- The analysis presumes that the airbases currently hosting Flankers will continue to do so in a contingency. We assume that the nature of maintaining advanced aircraft is

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277 Again using PLA Suixi as an example, the new, post-attack sortie rate and contribution to CAP is then calculated using 12.5 aircraft (24 original – 11.5 destroyed) operating from PLA Suixi.
fundamentally different from maintaining China’s vast fleet of obsolete aircraft, and that this maintenance capability has only been integrated into a subset of PLA airbases (those currently hosting Flankers and a handful of other possible contingency locations). If this is not the case, and the aircraft could disperse to any airbase in the theater, attacking them would be considerably more difficult (provided the dispersal bases have shelters).

- Tactical surprise is necessary, and we assume that the aircraft cannot “scramble” to dispersal bases upon receiving warning of an attack. Attacks on airbases should be combined with efforts to degrade command and control to prevent individual fighter regiments from receiving warning and dispersing. These efforts could be electronic attack or physically destructive attack.

- The analysis presumes the availability of the ideal weapons for the task – especially the submunition-armed TLAM-D. If submunition weapons are not available, one standoff weapon would be required per revetment – greatly increasing the number of weapons required.

- The analysis treats the effectiveness of PLA air defenses parametrically. If air defenses succeed in destroying many or most USAF standoff weapons, the effectiveness of attacks would be greatly degraded. Further, if airbases have point defenses that jam guidance systems or destroy electronics, the accuracy of USAF would be less than stated, and could result in large CEPs and fewer kills. If this effect were severe, destroying hardened aircraft shelters (which requires more precision) could be very difficult. Submunition weapons would be less affected by degraded guidance accuracy.

Conclusions

PLAAF and PLANAF higher-end fighters today operate from a variety of bases, including some bases with revetments, some with hardened
aircraft shelters, and some with underground tunnel shelters. Cratering operating surfaces demands many weapons, and would only be temporarily effective. Attacking parked aircraft would be a more robust and permanent option. Standoff weapons with submunition dispensers would be effective against Flankers parked in revetments. Standoff weapons with unitary warheads would also be very effective in targeting hardened aircraft shelters. Underground hangars would be very difficult to attack with standoff weapons. The best approach may be to harass these airbases in order to force the aircraft to use the shelters.

Standoff attacks should be directed at airbases hosting the most-capable PLA aircraft and prioritized by the softness of the target. Attacks should occur in force to overwhelm PLA air defenses. We estimate that one large attack with 198 standoff weapons could destroy many aircraft and degrade PLAAF/PLANAF sortie generation significantly. Roughly double that number would be required to achieve the same effect if each base that currently has revetments was upgraded to hardened aircraft shelters. This suggests that attacking PLA airbase infrastructure could be an important part of winning the air war for Taiwan, especially given how stressed USAF air superiority assets would be if PLA sortie generation were not disrupted.

SUMMARY OF OPTIONS

None of the alternatives explored is a panacea that fixes all of the problems associated with power projection in light of the western Pacific’s geography and PLA anti-access threats. Some of the alternatives explored return the USAF to a similar force ratio that would be achievable from Kadena AB. However, none of the alternatives can return the USAF to the quick response times and tactical flexibility that would be enjoyed at a fully-functional Kadena AB. This means that a PLAAF raid CONOP would still be at least theoretically an effective option. However, we can see in the table below that certain

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278 The effects of follow-on attacks are difficult to estimate without making too many assumptions regarding PLA post-attack and recovery actions.
alternatives could make such a CONOP very costly, perhaps infeasible for the PLAAF.
## Table 20
### Summarized Alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Aircraft Required</th>
<th>Effect - Potential Raid Stopped</th>
<th>Pro</th>
<th>Con</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status Quo</td>
<td>96 F-22s</td>
<td>36</td>
<td></td>
<td>-Unable to protect high-value aircraft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Serious strategic implications</td>
</tr>
<tr>
<td>Hardening Close-in Airbases</td>
<td>n/a</td>
<td>n/a</td>
<td>-Aircraft at Kadena AB or other close-in airbase can be reasonably protected</td>
<td>-Hardening cannot ensure efficient sortie generation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Funding military construction outside CONUS is difficult</td>
</tr>
<tr>
<td>Increase MOG at Andersen AFB</td>
<td>184 Fighters</td>
<td>66</td>
<td>-Increased ability to stop raid</td>
<td>-Response time still problematic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Greater reward for successfully attacking Andersen AFB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-MILCON outside the CONUS is politically difficult</td>
</tr>
<tr>
<td>Increase On-station Missile Magazine</td>
<td>96 F-22s with external armaments</td>
<td>21</td>
<td>-None</td>
<td>-Forfeits many F-22 advantages</td>
</tr>
<tr>
<td></td>
<td>96 F-22s with mixed internal/external armament</td>
<td>52</td>
<td>-Increased ability to stop raid</td>
<td>-Decreased stopping power</td>
</tr>
<tr>
<td></td>
<td>96 F-22 plus one to two air-to-air B-1s</td>
<td>72-108</td>
<td>-Greatly increased on-station counter-air capability</td>
<td>-Response time still problematic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Increased tactical difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Expensive development track</td>
</tr>
<tr>
<td>Degraded PLAAF Sortie Generation</td>
<td>Any combination above, with bomber sorties</td>
<td>Sortie generation decreased, up to 50% for 198 standoff weapons</td>
<td>-High-leverage option to reduce the force with which limited USAF counter-air assets must contend. -Destroying PLAAF aircraft on the ground would permanently reduce PLAAF sortie generation potential</td>
<td>-Attacking mainland airbases would be escalatory, or infeasible under some circumstances. -Effectiveness of attacks is contingent on PLA air defenses and PLAAF ability to disperse</td>
</tr>
</tbody>
</table>
If none of the alternatives above are by themselves completely satisfactory, a combination approach may be the most promising. In particular, attacks on PLAAF airbases would be a natural pairing with any of the approaches for increasing the firepower of the limited air superiority assets the USAF could generate from Andersen AFB. Attacks on PLAAF airbases would degrade the PLAAF side of the force ratio; increasing the USAF missile magazine would bolster the USAF side, and provide an enhanced capacity to deal with whatever PLAAF aircraft survived ground attacks.

Combination Approach for Overcoming Access Challenges

A course of action which best balances the protection of USAF forces and the demands of this contingency would trade time for the viability of U.S. airpower.

- **First, do no harm.** Any response to Chinese aggression across the straits should avoid putting significant combat power within easy reach of PLA attacks. Any force intended to be a deterrent, if unsheltered in the open within range of PLA TBMs, may instead become a tempting target. At a minimum, a deterrent that is not survivable is no deterrent at all. U.S. planners should not mistake actions that worked in the past for viable deterrent options in this scenario.

- **Use long-range strike options to degrade PLAAF offensive power.** The only alternative which almost completely bypasses the problems associated with using short-range fighter/multirole aircraft is striking PLA airbases. USAF long-range strike would be very effective in this role, as would Navy SSGNs. The previous examination only looked at one large standoff weapon raid, and found that we could reasonably expect 198 weapons to destroy 100-115 PLA Flankers and cut their force generation in half. The number of weapons required to achieve this effect would roughly double if every PLA airbase discussed had 24 hardened aircraft shelters built. The effect of subsequent raids was
not examined, largely because it would be contingent on too many assumptions regarding PLA post-attack and recovery actions. However, it appears that a long-range strike campaign could achieve significant effects.

- **Once PLA offensive airpower is degraded, use air superiority assets to secure Taiwan’s airspace.** If China’s ability to generate combat power is unmolested, USAF airpower in the Taiwan area would not be viable. The vulnerability of high-value ISR and tankers would make a PLAAF raid CONOP feasible, even in the face of the F-22’s superior capabilities. However, once PLA forces were degraded, limited USAF forces will have to contend with smaller numbers, and PLAAF raids would result in the losses of a greater proportion of their dwindling force. If no measures have been taken to increase the USAF on-station air-to-air missile number, the destruction of PLA airbases and aircraft would need to be more complete before this phase would be viable. If some of the alternatives to increase the USAF on-station missiles have been pursued, this phase could begin earlier.

These three actions could be the basis for a viable plan to deal with the geography and anti-access inherent in a U.S.-China-Taiwan conflict. The approach would combine the abilities of USAF (and USN) long-range strike with enhancements to the firepower and effectiveness of the limited counterair assets that would be available.

The key drawback in the approach is that it would require Taiwan to be largely self-sufficient until U.S. long-range strike could make the area safe for USAF high-value aircraft. Thus, any approach which trades time for viability needs to be coupled with efforts to increase Taiwan’s (temporary) self-sufficiency, giving Taiwan the ability to endure punishment (and perhaps even repel an invasion) until the USAF regains the ability to protect its airspace.

This may be disconcerting to Taiwan and to any concerned with Taiwan’s well-being. Taiwan could certainly incur significant damage in
the time before the USAF was able to re-enter its airspace. However, this is only a fatal criticism of this approach if our goal is to prevent any harm from coming to Taiwan. Unfortunately, that goal is wishful thinking under almost any circumstances: China’s large TBM force could inflict serious punishment on Taiwan regardless of how quickly the United States could seize air superiority over the Taiwan area. However, if the USAF goal is to reduce the overall threat to Taiwan of cross-strait aggression, an approach which trades time for viability is certainly better than a reactionary plan which attempts to do too little, too soon; and which could result in the destruction of U.S. airpower in the Pacific.
7. CONCLUSIONS

POLITICAL ANALYSIS AND THE RISK OF CONFLICT

Why ought we care about the possibility of war in the western Pacific, especially at a time when tensions seem to be easing and the United States is engaged in two enduring irregular wars? In short, war may not be likely in the immediate future, but there is still risk. Further, war does not seem likely in large part because of the U.S. conventional deterrent. But if this deterrent were eroded by Chinese antiaccess efforts and U.S. complacency, conflict becomes more likely and averting conflict engenders more costly losses of power and prestige. Without a strong U.S. military presence, the western Pacific would be more dangerous.

Despite encouraging signs, the U.S.-China relationship remains risky. This work examined two international security perspectives on conflict generation to determine whether or not there is risk of war in the U.S.-China relationship. The hegemonic change perspective documents situations where rising states challenge the hegemon for control of the international system, often violently. While the U.S.-China relationship is roughly congruent with this explanation, the current open, multi-lateral, and liberal world order may make power shifts less violent in the future.

Empirical studies of conflict also expose some concerning elements in the U.S.-China relationship: a shift in relative power, China’s growth in power, a rough balance in national capability, the tactical advantage China enjoys in the western Pacific, and, in the future, the possibility for democratization in China. Only the large trade magnitude between the two states is encouraging.

Whatever the macro trends that make conflict more or less likely, wars still require catalysts. The most likely catalyst in this case is the lingering uncertainty over the status of Taiwan. The Taiwan problem features two armed camps with almost mutually exclusive goals. In addition, the governments in Beijing and Taipei generally have trouble communicating, which raises the risk that an otherwise manageable crisis
could become something much worse. If there is U.S.-China conflict, Taiwan is the most likely flashpoint.

Preventing a U.S.-China-Taiwan war is both a diplomatic and a military endeavor. In order to help China and Taiwan to resolve differences peacefully, all parties should take steps to encourage and enhance cross-straits dialog and cooperation. In addition, incorporating China into strong, multilateral institutions will give China a presence in the international system commensurate with its growing hard power, and give China an attractive alternative to brandishing that hard power.

This is not to say, however, that military preparation for a U.S.-China-Taiwan conflict is moot: diplomacy works best when words are backed by military force. While engaging China, the United States needs to hedge by enhancing its capability to defend Taiwan. A strong military capability would lend credibility to diplomatic negotiations, and should continue to tilt China’s cost-benefit calculation towards the peaceful resolution of differences. Ideally the use of force will not be necessary; but the availability of credible military options would help ensure that those military options will never be used.

We may be tempted to draw the conclusion that, given that such a conflict would be so difficult to win, the United States should begin to back away from its commitment to Taiwan. However, there would be very serious repercussions from abrogating our regional commitments, repercussions that may be as bad as fighting and failing to win a U.S.-China-Taiwan conflict.

U.S. allies in the area would doubt the strength of the U.S. commitment to them, and we could see large-scale defection. Japan, unwilling to leave regional hegemony to China, might choose to bolster its own military—perhaps by developing nuclear weapons. The region could become very dangerous. Beyond the effect on U.S. allies, if the United States cannot fulfill its commitment to Taiwan in the future, the United States would have essentially ceded regional hegemony to China. This would be a severe blow to U.S. power and prestige. In the long run, some adjustment in regional power between the United States and China may be inevitable anyway. If this is the case, it would be better
if the United States could make transition arrangements on its own terms, and at least leave in place a security architecture that would shape the region in a peaceful direction. However, the abrupt departure of U.S. power from the region would leave a dangerous power vacuum. If the United States does nothing to bolster its capabilities to defend Taiwan, or actively retreats from defending Taiwan, the strategic repercussions would be severe.

ANTIACCESS CHALLENGES AND IMPLICATIONS

In the event of a conflict in the western Pacific, and in planning to prevent a conflict, the USAF needs to come to terms with the severity of the airbase-denial effort it faces. To begin with, the geography of the western Pacific is particularly suited to antiaccess strategies. On top of this, China has focused its resources on developing capabilities (especially large arsenals of theater ballistic missiles) that asymmetrically counter the U.S. way of war—especially using large, secure staging areas (like airbases) to project overwhelming force. After constraining the size of USAF forces that can be brought to bear, the PLAAF can counter U.S. technology with superior numbers and tactical flexibility.

The western Pacific comprises vast expanses of open water, with little landmass available for short-range fighter and multi-role aircraft. The natural dearth of airbases in the region means that the threat to each airbase is more significant than it would be in a theater with more basing options. These threats include political access-denial efforts, special operations forces, cruise missiles, and ballistic missiles.

The ballistic missile threat in particular is very challenging due to the difficulty of effectively intercepting missiles, coupled with the sheer number of missiles in China’s inventory. Other research has shown that ballistic missiles armed with submunition warheads could cover large areas of parking ramps and operating surfaces, rendering anything parked in the open destroyed or severely damaged. RAND work shows that
only 34 weapons could destroy virtually every airplane parked at Kadena AB.\textsuperscript{279} Airbases further from the threat are not immune, China has a variety of missiles capable of ranging most airbases in Indochina, the Philippines, or Japan.

For the time being, Andersen AFB is outside the immediate threat, although that could change if China began a push to convert old ICBMs or build new missiles for the long-range, conventional attack role. Considering the threat to Kadena AB and other close-in airbases, it is a distinct possibility that a hypothetical U.S.-China-Taiwan conflict would have to be fought primarily from Andersen AFB.

**SORTIE GENERATION AND PLAAF CONOP**

The current USAF inventory was designed and optimized for European operations, where basing was close to the likely area of conflict. The Pacific theater, especially in light of anti-access threats, is very different. An Andersen AFB-only scenario would hurt USAF force projection in several ways:

- Long flight times would demand a large amount of aerial refueling. The requirement to base refueling aircraft would leave less room for fighters.
- The long mission duration and limited basing would reduce the achievable sortie rate, meaning that on a daily basis, PLAAF sorties would greatly outnumber USAF sorties.
- The transit time from Guam to Taiwan would limit the ability of USAF aircraft to respond to events in the airspace around Taiwan. This means that, in order to defend Taiwanese airspace or USAF high-value aircraft, a constant defensive counter-air patrol would be necessary. Further, that patrol would be on its own in stopping PLA aircraft - meaning that the PLAAF would have tactical flexibility that the USAF could not match.

\textsuperscript{279} Stillion and Caston, “Operating Airbases Under Attack.”
It is clear that the USAF F-22 is much better than any aircraft in the Chinese inventory, including the 4th-generation Su-27s, Su-30s, and J-11s. However, it is unclear if the F-22’s qualitative superiority can overcome being outnumbered 6:1 on a daily basis, or being outnumbered even more for short periods of time during postulated PLAAF raids. Even if the F-22 were completely invulnerable to enemy BVR attacks and its air-to-air missiles could down or scatter their targets every single time, some PLAAF aircraft would survive unmolested. These aircraft could engage USAF high-value aircraft: ISR, AWACs, and tankers. Even with very ineffective air-to-air missiles and no deconfliction between PLAAF pilots, a high proportion of high-value aircraft would be engaged and destroyed. This type of PLAAF raid CONOP would make persistent USAF airpower over Taiwan unviable.

WIDER MILITARY IMPLICATIONS

The security changes in the western Pacific may be the beginnings of a paradigm shift in military operations. The United States is accustomed to enjoying a large, secure basing footprint with secure staging areas and unhindered lines of communication. With these prerequisites the United States has been able to mass overwhelming force - quantitatively and qualitatively - in order to prevail against lesser opponents in the Gulf War and the early (pre-insurgency) phases of OIF and OEF. To some extent, this dominance is understood as the norm, and that large, secure bases of operations are taken for granted. Lessons from previous conflicts and the attention paid to defenses and recovery actions in the Cold War, if not forgotten, are not necessarily emphasized. If the United States is serious about the capability to deter and defeat a peer or near-peer adversary, the United States needs to re-understand the expectations.

A peer or near-peer adversary is serious and strategic. Fighting a near-peer adversary would not resemble the asymmetric, irregular war for which the U.S. military is (currently) being adjusted to fight. The campaign would not look like the bombings of relatively defenseless 3rd world countries. If the United States is serious about responding to
growing challenges, it needs to become re-acquainted to thinking about fighting a near-peer adversary.

The U.S. conception of deterrence has been to flow forces to forward operating bases to signal a potential deteree that the United States is serious. The general impression is that these measures succeeded in deterring China from escalating against Taiwan in 1996, when the U.S. forward-deployed two carrier battle groups. However, if the U.S. were to follow the same course of action in a crisis today, the outcome could be very different. What is different between 1996 and now, let alone a 2015 timeframe, is that in 1996 China could not counter the U.S. forces in the area. Today, China has a number of force options available to attack U.S. forces at Kadena directly. Means for attacking an aircraft carrier (like the ASBM) is in development. Means for conventionally attacking U.S. forces further away than Kadena are currently limited, but we note that developing additional capability is well within the technical ken of China, and would not take very long. The United States learned during the Cold War the nuclear deterrence needs to be survivable against a first strike: a similar lesson could be applied to conventional deterrence. If conventional deterrence is not survivable, it would be more destabilizing than deterrent. If a force were not survivable, a different approach to deterrence would be necessary.

This observation also suggests that U.S. forces need to be balanced for offensive power and survivability. In other words, spending on new aircraft does not deliver a credible capability if those aircraft do not have secure locations from which to operate. It is important to realistically consider where new aircraft will be deployed and how to protect them once there. The corollary to this observation is that, given the choice between new weapons and defenses, the next marginal dollar should be spent on defenses.

The implications of PLAAF sortie generation potential and relative tactical flexibility remind us that better technology does not necessarily lead to air dominance. Singly dominant fighters in low numbers may not be enough to overcome large numbers of less-capable aircraft. A strategic adversary can devise ways to "pose problems
The USAF needs to consider the trade-off between quality and numbers. In the Cold War, this trade-off motivated the development of the F-16, which was to be available in large numbers at relatively low cost, complementing the higher-capability but more expensive F-15. This was also the initial vision for the F-35, but with unit costs rapidly approaching the unit costs of the F-22, it is uncertain whether affordability will be able to compensate for its admittedly lower air-to-air capability. Despite the remarkable capabilities of USAF fifth-generation aircraft, pitting relatively few fifth-generation aircraft against very large numbers of fourth-generation fighters is, at best, and untested strategy.

We also note that the success of USAF fighters is highly dependent on the ability of USAF air-to-air missiles. While this effort does not make an effort to predict the AMRAAM’s Pk precisely, we note that when employed against maneuvering adversaries using decoys and countermeasures, its performance would probably be well under its historical average (tallied largely against non-maneuvering adversaries with inoperable or wholly inadequate avionics). Large investments in highly capable fifth-generation aircraft must be balanced with investments in air-to-air weapons which complement the platforms’ capabilities. Without an air-to-air missile that can reliably hit targets, each USAF aircraft would not be able to destroy enough PLAAF aircraft to overcome their superior numbers. In effect, the USAF would have a large number of largely invulnerable raptors, sans talons.

If, indeed, attacks on staging areas combined with a PLAAF raid CONOP could deny U.S. air superiority in a Taiwan conflict, strategies for that conflict would need to include an expectation – or at least a contingency plan – for a lack of U.S. air superiority. This would be a very difficult change, as the U.S. military has never really had to

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280 To paraphrase the title of Christensen, “Posing Problems Without Catching Up.”

281 The argument to proceed with such a strategy was essentially a Lanchestrian one, posited by Kent et al., Thinking About America’s Defense: An Analytical Memoir, Santa Monica, RAND, 2008, pp. 232-235.
fight without at least some measure of air superiority over the battlefield.  

We also find that if Guam were rendered unusable by attacks (or the threat of attacks), defending Taiwan directly would become a nearly impossible task. Only long-range options would be feasible, and any plan to that effect would rely heavily on coercion and punishment. A worst-case fallback would be to wait for the PLA to expend its missile magazine before moving forces forward, but it is far from clear that Taiwan could defend itself that long, or that the PLA would not hold a sizeable portion of the missile magazine in reserve, preferring to keep enough of an inventory to hold U.S. forward deployments at risk indefinitely.

ALTERNATIVES

No alternatives present a panacea solution to the challenges USAF force projection faces. The most promising approach would likely be a combination of efforts to address both the “supply” and “demand” side of sortie generation.

Addressing the “demand” for USAF air superiority forces means decreasing the force the USAF would face in the air. In a crisis in the western Pacific focused on Taiwan, the U.S. military should explore degrading PLA forces with airbase attacks – using USAF bombers and USN SSGNs. This effort should continue until PLAAF sortie generation capabilities are significantly degraded and the PLA has expended its inventory of ballistic and cruise missiles threatening U.S. airbases – only then should USAF air superiority assets be moved to forward locations. Any tactic that would encourage China to expend more of

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282 It is important to note that in WWII the U.S. did prosecute raids into areas without local air superiority. This was accomplished, initially with very high losses, using massive bomber raids escorted with fighters to overwhelm enemy defenses. Future U.S. CONOPs for air-superiority-free operations could take a page from these operations.

283 “Forward locations” certainly include Kadena AB and other airbases within similar distance of mainland China. “Forward locations” could contain Andersen AFB as well if China has developed the capacity to attack it with decisive force.
its weapons is worth investigating. Possibilities include passive defenses (hardening), which would require stronger attacks to achieve the same purpose; parking decoys on the ramp; or if decoys fail, parking less-valuable or mostly broken aircraft on the ramp to encourage attacks.

Addressing the “supply” side of the force projection problem includes any action to increase the number of counter-air weapons the USAF can put on station, or improving those weapons’ effectiveness. Some approaches explored in this work include increasing the MOG at standoff airbases, developing new counter-air weapons systems, or practicing tactics to seamlessly combine stealth and non-stealth fighters. “Supply” side approaches are complementary to any approach to degrade PLAAF sortie generation.

CAVEATS

I have previously noted the limitations of this dissertation’s scope and its conclusions. The dissertation was not intended to encompass the entire security picture, nor every domain of the battlespace. This dissertation described a case for the feasibility and risk of armed conflict and touched on, but did not fully develop, the ways in which armed conflict could occur and how it might evolve. On a purely military level, naval warfare and the ground battle were treated lightly in order to isolate the air superiority fight. Likewise, certain aspects of a hypothetical air battle (notably air defenses and the ROCAF contribution) were treated lightly in order to isolate other variables and to deal with information scarcity.

Future work on this topic should seek to add in some of these omitted factors. The political picture could be made more complete with a thorough examination of the likely progression of crisis management, the pitfalls inherent therein, the possible courses of action of the major players if conflict commenced, and the possible exit strategies available to the powers involved.

Since a number of factors were not discussed or held constant by assumptions in order to isolate the main themes of an air superiority struggle, future studies could benefit from selective additions back
into the military analysis. Prospective areas for future research include, but are not limited to, a more thorough picture of other nations’ contributions to the air war; real-world fifth-generation fighter sortie data; the effect of layered IADs; and the interlocking effects of air, naval, ground, space, and cyber domains of warfare on each other.

Despite these limitations, this dissertation leads us to several important insights.

CONCLUSIONS

Geography and China’s anti-access threats make a scenario where the USAF only operates from Andersen AFB very possible. In this case, the USAF would find it very difficult to project power, and a PLA/AF CONOP using superior numbers to raid vulnerable USAF aircraft could displace U.S. airpower in the western Pacific.

The discussion and analysis in this work show that this conflict, if it were to occur, would be much harder to win and would be much more costly to the United States than other recent conventional conflicts. In fact, winning would not be a foregone conclusion— as has been the case in all conventional conflicts since the end of the Cold War. Further, if U.S. leadership dismisses or ignores the threats to regional airbases, not only could the United States fail to win this particular conflict, but the United States could lose the greater portion of its airpower in the process.

Avoiding the scenario will require more than faith that China will not use its ballistic missile force, will require more than the F-22 (as good as it is), and will require more than a complacency that a conflict over Taiwan will never happen. While the U.S.-China relationship seems stable at the moment, there is yet some risk, and the U.S. military exists to prepare for wars that hopefully never occur, thereby preventing them. Responding to PLA modernization, especially antiaccess capabilities, will require creative solutions on the part of the USAF and U.S. military as a whole.
A. USAF SORTIE GENERATION MODEL

INTRODUCTION

To quantify the difference in operations from Kadena AB and Andersen AFB, the author developed a sortie rate model. This model builds on previous unpublished work by Lawrence Hollett, used and developed further in Stillion and Orletsky. This model adds to previous work by incorporating aerial refueling considerations.

This model predicts the notional steady-state combat air patrol (CAP) that could be supported by a given number of aircraft at a given location. We choose this measure of effectiveness (CAP size) because it is simple and easily comparable across locations. While we recognize that air campaigns are more multi-faceted than simply populating one large CAP, this measure will shed light on the challenges inherent in operating fighter aircraft over large distances, and allow for easy comparison between baseline (i.e. Kadena AB) and standoff (i.e. Andersen AFB) force postures, as well as easy comparison between USAF sortie generation capabilities and PLAAF/PLANAF sortie generation capabilities.

A number of limitations characterize the force that can be generated from a particular airbase. Most fundamentally, an airfield can only support a limited number of aircraft. This number is called the “maximum on ground” (MOG) - and is a composite estimate taking into account parking spaces, fuel capacity, and the traffic that airfield operations can handle. Here we will use the MOG at Andersen as a hard upper limit on the number of aircraft that can deploy there. This number will need to include the full mission spectrum - fighters, bombers, ISR/AWACS, and the tankers that allow these aircraft to traverse the long distance from Guam to the Taiwan area of operations.

285 Stillion and Orletsky, Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks, p. 81.
We will break this consideration of sortie generation into two broad areas: actions performed in the air and actions performed on the ground.

**INFLIGHT ACTIONS**

Inflight actions include cruising to a CAP, on-station time, returning to base, and the in-flight refueling that must occur. Total flight time is simply

\[
\text{Flight time} = 2 \text{ cruise time} + \text{Time on Station} + \text{Refueling Time}
\]

Where cruise time = \(\frac{\text{Distance to CAP}}{\text{Cruise Speed}}\)

The distance to the CAP, the cruise speed, and time on station are given or constants. Refueling time is the number of refuels required to perform a mission and the duration of each refueling. Determining the number of refuels required is a somewhat iterative process. At a minimum, the aircraft must take on enough fuel to sustain the cruise to and from the CAP as well as the time on station. The aircraft starts with a full tank of fuel, and must only finish with a sufficient reserve. The total fuel required for the mission is a product of the time spent cruising and the hourly fuel flow, plus the fuel burned while on station (for this analysis, we assume that aircraft require one full tank minus reserve for combat maneuvers while on station). The total fuel required, less the reserve and starting fuel, forms the low estimate of required inflight fuel. The minimum number of refuels is the total required divided by the amount that can be taken on at any one time.

\[
\text{Total fuel required} = \text{Cruise Time} \times \text{Cruise Fuel Flow Rate} + \text{One Full tank} - \text{Fuel Reserve}
\]

\[
\text{Minimum Inflight Fuel Required} = \text{Total Fuel Required} - (\text{One Full Tank} - \text{Fuel Reserve})
\]

The length of a single refueling event is determined by how long it takes to rendezvous with the tanker, how many aircraft are flying in
a formation and receiving fuel, and how long it takes a single aircraft to refuel. The last factor is simply how much fuel is required divided by the lesser of the fuel offload rate and the fuel acceptance rate. For fighter aircraft, fuel acceptance rate is generally the limiting parameter.

Single Refueling Time = Flight Rendezvous Time + Number Aircraft (Time to Boom + time to refuel)
Where time to refuel = fuel required / fuel accept rate

In practice this refueling time varies somewhat - not every refueling event demands refilling an empty fuel tank. This is taken into account. Once we have the number of refuelings required and the time it takes to refuel once, it is a simple matter to calculate the total time spent refueling per sortie.

The above calculations describe the time required to undertake all necessary in-flight actions. We now turn to a consideration of the time spent on the ground recovering from a previous mission and preparing for the next.

GROUND TIME

The time spent on the ground between missions includes all the actions necessary to recover an aircraft and prepare it for its next mission. This encompasses all of the actions that occur once an aircraft lands until it is ready to take off again. Besides maintenance, the durations of these actions are relatively constant. For example, taxiing from a hardstand to a runway will take a certain amount of time at any reasonably similar airbase. Refueling is somewhat standard, as is the time to rearm. The duration of these actions, in minutes, are detailed in the following table. We will treat these actions separately from maintenance.
### Table 21
Standard Times to Complete Aircraft Turnaround Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and Taxi</td>
<td>10</td>
</tr>
<tr>
<td>Make Aircraft Safe for Ops</td>
<td>5</td>
</tr>
<tr>
<td>Shut Down Systems</td>
<td>2</td>
</tr>
<tr>
<td>Conduct Post-Flight Inspection/Debrief</td>
<td>15</td>
</tr>
<tr>
<td>Re-arm</td>
<td>50</td>
</tr>
<tr>
<td>Service</td>
<td>20</td>
</tr>
<tr>
<td>Refuel</td>
<td>30</td>
</tr>
<tr>
<td>Conduct Pre-Flight Inspection</td>
<td>15</td>
</tr>
<tr>
<td>Start Engine</td>
<td>5</td>
</tr>
<tr>
<td>Perform Final Systems Check</td>
<td>5</td>
</tr>
<tr>
<td>Arm</td>
<td>5</td>
</tr>
<tr>
<td>Taxi</td>
<td>10</td>
</tr>
<tr>
<td>Wait in Queue</td>
<td>5</td>
</tr>
<tr>
<td>Take Off</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>180</strong></td>
</tr>
</tbody>
</table>

NOTE: Times in minutes

Required maintenance depends on the amount of wear-and-tear or damage endured on a mission. This factor has the potential to vary wildly aircraft to aircraft. However, on average, Craig Sherbrooke has found that required maintenance tends to aggregate linearly based on flight time. Some aircraft will be completely mission-capable upon

---

286 "These turnaround times represent typical performance of USAF maintenance personnel in force-employment exercises conducted during the late 1980s and early 1990s, as determined through interviews of senior F-15 and F-16 maintenance personnel by J. Lawrence Hollett in 1995. While it may appear that substantial time could be saved by performing the post-flight inspection, re-arming, service, and refueling operations in parallel, safety considerations prevent doing so. When refueling or re-arming operations are in progress, only fuels and munitions personnel are permitted near an aircraft." Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks*, p. 83.

287 Craig Sherbrooke, *Using Sorties vs. Flying Hours to Predict Aircraft Spares Demand*, McLean, Va: Logistics Management Institute, April 1997. These findings are based on a study of F-15 and F-16 maintenance, but we will use them for F-22s as well. Given that the F-22 was designed to have a smaller maintenance footprint than an F-15, (Continued on the next page).
landing; they can do a very quick combat turn and be back in the air very quickly (though with a new crew if the mission is a long one). Other aircraft will not be mission capable, and will require extensive maintenance - much more than is predicted. All told, the average maintenance time is predicted to be 3.4 hours plus .68 hours of maintenance for every hour of flight time.\(^{288}\) Since this work is looking at the expected sortie generation of a relatively large number of aircraft, it is reasonable to use this estimate (if the number of aircraft considered were very small, it would be necessary to examine the discrete effects in more detail). After a mission, the total expected time on the ground for an aircraft is simply:

\[
\text{Time on Ground} = \text{Ground Actions} + \text{Maintenance Time} = 3 \text{ hrs} + 3.4 \text{ hrs} + .68 \times \text{Flight time}
\]

The maintenance time shown above is just a predicted average. This predicted average will be observed only when there is an adequate maintenance capacity. If not enough capacity exists, aircraft requiring maintenance will be waiting in queues for long periods of time. For the purposes of this discussion, adequate maintenance capacity is assumed to exist. For a more thorough discussion of the maintenance queuing implications, see Appendix B.

**CREW CONSTRAINTS**

The time pilots must spend in the cockpit is also considered. An important constraint is that aircrews are not an unlimited resource - pilots can only be on duty for so long before becoming fatigued. The ratio of aircrew/aircraft is generally more than one, which means that a single aircraft may be flown by two or more different pilots in the course of one day. Thus, the model includes a constraint that the total stretch should not be problematic. There are some considerations given to unique problems associated with low-observable maintenance. These are discussed in Appendix B.

\(^{288}\) Craig Sherbrooke, Using Sorties vs. Flying Hours to Predict Aircraft Spares Demand.
flight hours for the fleet will not exceed the total time that aircrew are available. For this analysis, the constraint turns out to be nonbinding, as the long mission duration means that average maintenance time exceeds the time required for aircrew duty rest.

SAMPLE CALCULATIONS

The model developed repeats this calculation for a user-inputted beddown of aircraft. User inputs include whether each sortie is a 2-ship or 4-ship, crew ratio, location of beddown, and location of the CAP. The model returns the steady-state CAP size, refueling required, and the total fuel the operation requires per day.

A sample calculation for F-22s at Andersen AFB, flying in 2-ships, on station for 1.25 hours at the centerpoint of the Taiwan Strait, and with 1.25 crews per aircraft follows:

Table 22
Relevant Aircraft Data

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise Speed</td>
<td>520 ktas</td>
</tr>
<tr>
<td>Fuel Capacity</td>
<td>18,000 lbs</td>
</tr>
<tr>
<td>Fuel Burn Rate, Cruise</td>
<td>8,000 lbs/hr</td>
</tr>
<tr>
<td>Fuel Acceptance Rate</td>
<td>3,000 lbs/min</td>
</tr>
</tbody>
</table>

Flight Time Sample Calculation

First we calculate flight time:

\[
\text{Flight time} = 2 \frac{\text{Distance to CAP}}{\text{Cruise Speed}} + \text{Time on Station} + \text{Refueling Time} = 2 \frac{1560 \text{nm}}{520 \text{ktas}} + 1.25 + \text{refueling time}
\]

---

The cruise time from above is 3 hours each way. We assume that while on station, maneuver burns up one full fuel tank, not including the reserve. A required reserve of 10% of fuel capacity is used. It follows that

\[
\text{Total fuel required} = 2 \times (3 \text{ hrs} + 1 \text{ hr}) \times 8000 \text{ lbs/hr} + 18000 \text{ lbs} - 1800 \text{ lbs} = 64135 \text{ lbs}
\]

\[
\text{Minimum Inflight Fuel Required} = 64200 \text{ lbs} - (18000 \text{ lbs} - 1800 \text{ lbs}) = 39800 \text{ lbs}
\]

Satisfying this fuel demand would require at least two refuelings en route, one roughly 1,000 nautical miles from Andersen AFB, and another to “top up” right before entering the CAP. Three refuelings would be more robust to unforeseen events, but would not change the requirements calculations a great deal. Each refueling lasts roughly 15 minutes (see below).

The length of time it takes to refuel once is shown below:

\[
\text{Single Refueling Time} = \text{Flight Rendezvous Time} + \text{Number AC (Time to Boom} + \text{time to refuel)}
\]
\[
\text{Where time to refuel} = \frac{\text{fuel required}}{\text{fuel accept rate}}
\]

\[
\text{Single Refueling Time} = 2 \text{ min} + 2 (1 \text{ min} + 6.5 \text{ min}) = 15 \text{ min}
\]
\[
\text{Where time to refuel} = 16200 \text{ lbs} / 3000 \text{ lbs per min}
\]

Based on the above calculations, a single mission would last roughly 8.25 hours, which includes 6 hours en route, 1 hour of refueling (four separate refuelings lasting 15 minutes each), and 1.25 hours on station.

**Ground Time Calculation**

Recall from above that the on-ground turnaround actions consist of roughly 3 hours of taxiing, inspection, etc. in addition to any required maintenance. On average, this consists of 3.4 hours of maintenance per
sortie plus an additional .68 hours of maintenance per hour of flight time.\textsuperscript{290} Total ground time is thus:

\[
\text{Ground actions} + \text{Fixed Maintenance} + \text{Variable Maintenance per Flt Hr} = 3\text{hrs} + 3.4\text{hrs} + .68(8.25\text{hrs}) = 12\text{hrs}
\]

The average turnaround time for a mission plus the ground time before the next mission is simply

\[
\text{Flight time} + \text{Ground time} = 8.25\text{hrs} + 12\text{hrs} = 20.25\text{hrs}
\]

For 24 hour operations, this turnaround time is translated into a daily sortie rate and a steady-state CAP strength delivered from this base.

\[
\text{Sortie Rate} = \frac{24\text{hrs}}{20.25\text{hrs}} = 1.2 \text{ sorties/day}
\]

\[
\text{CAP size} = \text{number aircraft} \times \text{sortie rate} \times \left(\frac{\text{loiter time}}{24\text{hrs}}\right) = 6 \text{ F-22s on Station}
\]

This result is checked against a pilot flight time constraint, 12 hours a day before pilots are not fit to fly again. If we include a 2 hour pre-flight briefing, each sortie demands 10.25 hours of aircrew time. At 1.2 sorties a day per aircraft, each using 10.25 hours of crew time, 1.25 crews per aircraft\textsuperscript{291} is adequate. Crew flight time restrictions will be a nonbinding constraint.

\textsuperscript{290} Again, assuming adequate maintenance capability. See Appendix B for full discussion.

\textsuperscript{291} Tirpak, "F-22 is Battle Ready," pp. 46-52.
B. QUEUING CONSIDERATIONS

The previous discussion of sortie generation considered the case where each aircraft’s turnaround time was simply the time to complete a series of on-ground tasks (e.g. taxi, shut down systems, post-flight inspection, etc.) plus the average required maintenance. Previous work has shown that the average maintenance for F-15s scales linearly with the sortie duration: 3.4 hours plus .68 hours per hour of sortie duration.292

The F-22 is a relatively young aircraft, and USAF experience with the F-22 is not yet extensive enough to pin down a similar estimate. The average maintenance currently required is very likely much more than will be experienced in the future – something that is normal as new weapons systems are broken in and as maintainers progress along the learning curve. One of the requirements of the F-22 program was that the maintenance footprint was to be less intensive than the legacy F-15.293 If this goal is met, then the average F-15 maintenance should at least be a reasonable indicator of what we would expect from the F-22 in the future.

While the estimate used previously is a good indicator, on average, of how much maintenance time will be required for each aircraft, it may not tell the complete story. The estimate used previously indicates average maintenance required, not the average time an aircraft spends in maintenance or in a queue waiting for maintenance. The actual maintenance time can vary wildly. Some aircraft will require little to none, while others will require much more than average. Further, although the previous analysis considers a relatively smooth flow of sorties throughout a given day, the actual arrival of aircraft will

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292 Craig Sherbrooke, *Using Sorties vs. Flying Hours to Predict Aircraft Spares Demand.*

293 Tirpak, “F-22 is Battle Ready,” pp. 46-52. The 27th Fighter Squadron has “achieved an aircraft utilization rate equal to that of most F-15 and F-16 squadrons,” indicating that this estimate is reasonable.
still vary somewhat (for example, some may expend munitions quickly and be forced to return before their “allotted” on-station time is complete). If not enough maintenance capacity is present, aircraft will have to wait long periods of time before their required maintenance can begin.

We now turn to a brief consideration of the effect of these queuing considerations on average turnaround time. We postulate that the maintenance of returning aircraft can be represented as a first-in first-out queue with a Markov arrival and service processes (an M/M/s queue). While technically the problem we are considering would be represented by a finite queue, the maximum size of which would simply be the number of aircraft at the airbase, for simplicity an infinite queue model is used. The results will be practically the same, as the number of aircraft we consider at Andersen AFB is suitably large in relation to the number of servers (i.e. maintenance capacity) that we will consider. Three parameters define this queuing model: interarrival time, service rate, and number of servers. The parameters are analogous to the aircraft arrival rate, the amount of required maintenance for each aircraft, and the number of aircraft that can simultaneously have maintenance performed, respectively.

In considering the arrival rate of aircraft into the maintenance system, we are most concerned with the rate of aircraft returning to base. The previous analysis has assumed a constant CAP mission profile, with aircraft departing and arriving at a relatively constant rate. However, there would still be some variation in arrivals caused by unforeseen events. Here we assume that the time between aircraft arrivals is distributed exponentially, as is consistent with many queuing systems. If we have a daily sortie rate of 1.11, the mean interarrival time is .225 – 24 hours / (96 aircraft x 1.11 sorties/day).

Recall previously, the total mission duration for a 1.25 hour F-22 CAP mission over Taiwan was approximately 10 hours. Using the estimate above, we would expect F-22s flying an Andersen to Taiwan CAP mission to require 10.2 hours of maintenance, on average, upon their return (3.4 hrs + .68 x 10 hrs). Of course, few if any aircraft will require exactly 10.2 hours of maintenance, and there will be a distribution of
actual required maintenance with 10.2 hours as its mean. This distribution will be skewed such that most aircraft require relatively little maintenance and a small number will require a very great deal. To reflect this, we choose a Poisson distribution, the classic distribution for service time in queuing theory. This distribution will be defined with the mean of .098 aircraft served per hour (the inverse of 10.2 hours required maintenance).

   The number of servers in the queue is analogous to the number of aircraft that can be maintained simultaneously. We will vary this parameter to determine its effect on wait times.

   The results of this queuing examination (see table 23) show that adequate maintenance capacity is critical to sustaining high sortie rates. With 96 F-22s at full operations tempo, in order for the actual time in maintenance or awaiting maintenance to approach the predicted required maintenance, Andersen AFB would need the capacity (permanent or deployed) to do maintenance on five F-22s simultaneously. This would be in addition to the required maintenance capacity for all of the other aircraft that might be at Andersen AFB in a contingency. With a capacity to maintain five aircraft, the average wait time (before commencing maintenance) would be 22 minutes. The wait time decreases with added capacity - with a six-aircraft maintenance capacity it would only be 5 minutes. On the other hand, it increases dramatically if we subtract capacity - to 1.5 hours with four-aircraft capacity, 8.6 hours with three. With the capacity to work on only 2 aircraft simultaneously, the queue fails. Further, as the number of servers declines, the standard deviation of associated with the wait time becomes very large. In other words, at any given time, the wait time could be very high or nonexistent - and as maintenance capacity declines, it becomes more unpredictable.
Table 23
Maintenance Capacity, Wait and Cycle Times

<table>
<thead>
<tr>
<th>Simultaneous Maintenance Capacity</th>
<th>Wait Time</th>
<th>Total Cycle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Infinite</td>
<td>Infinite</td>
</tr>
<tr>
<td>3</td>
<td>8.6 hours</td>
<td>18.8 hours</td>
</tr>
<tr>
<td>4</td>
<td>1.5 hours</td>
<td>11.75 hours</td>
</tr>
<tr>
<td>5</td>
<td>22 minutes</td>
<td>10.5 hours</td>
</tr>
<tr>
<td>6</td>
<td>5 minutes</td>
<td>10.3 hours</td>
</tr>
<tr>
<td>7</td>
<td>1 minute</td>
<td>10.2 hours</td>
</tr>
<tr>
<td>8</td>
<td>None</td>
<td>10.2 hours</td>
</tr>
<tr>
<td>9</td>
<td>None</td>
<td>10.2 hours</td>
</tr>
</tbody>
</table>

What does this examination tell us? First, the capacity to work on several aircraft at once is essential to sustaining high operations tempo. The ability to do so is highly sensitive to even small changes in the number that can be maintained. From our baseline (5 servers), if 40% of the maintenance capacity were lost, the time spent waiting for required maintenance would increase 2,475%. This observation argues for a great deal of redundancy and spare capacity in any high operations-tempo environment. It also highlights the sensitivity of critical operations to attack, and reiterates the need to harden or make redundant every piece of the system that generates sorties.

A number of assumptions color this analysis. Most importantly, this analysis assumes that all maintenance functions are interchangeable and can be characterized by one single measure: required maintenance time. If we separated maintenance on different subsystems, and assumed that the malfunctions of the various subsystems are independent, the analysis would show a need for more maintenance capacity. Further, this analysis presumes that F-22 maintenance is similar to F-15 maintenance. There are some difficulties with maintaining a low-observable aircraft, namely that to obtain access to many subsystems requires removing low-observable material.294 This adds time and complexity to what would be

---

294 “Where parts are hard to get at, and they’re LO-intrusive, ... you have to tear it apart, put the part in, and then put it back

(Continued on the next page).
mundane tasks on other aircraft. Reapplying low-observable material requires some cure time.

Any large deployment to Andersen AFB needs to include adequate maintenance capability - enough to be robust to the random variation in aircraft wear and unexpected changes in plans. The maintenance capabilities, either organic or deployed, must be able to deal with the peculiarities of LO surfaces, and ongoing experience with LO aircraft will help the USAF develop a better understanding of these peculiarities. A cursory queuing examination implies that for the size operation examined in this dissertation, the hangar space, materiel, and manpower to maintain five LO aircraft simultaneously is necessary.

together, which is very time-consuming." Tirpak, "F-22 is Battle Ready," pp. 46-52.
C. PLAAF/PLANAF FLANKER SORTIE GENERATION CALCULATIONS

INTRODUCTION

In order to judge the effectiveness of the USAF air operation, we must explore what force the PLAAF could generate in opposition. Calculating what force China could bring to bear with its high-end fighters is similar to the calculations previously used for predicting USAF sortie rates. The main simplifying difference is that we need not consider the implications of refueling and refueling aircraft. The Flanker’s combat radius is sufficient to cover Taiwan without being refueled. China’s refueling fleet is also somewhat small, and would likely only play a ‘specialist’ role in campaigns for the foreseeable future.

POSTULATED BEDDOWN

The postulated disposition of PLAAF high-end aircraft is based in part on their current locations and in part on interpretations of PLA air campaign strategy. The beddown assumes that airbases currently hosting Su-27s, Su-30s, or J-11s will continue to do so in a contingency. This assumption is based on the maintenance differences between China’s higher-end aircraft and the large numbers of obsolete aircraft. Unless the PLA has made investments in maintenance capability at a large number of PLA airbases, it is likely that bases currently hosting Flankers will continue to do so. From a PLA perspective, this is not particularly problematic in terms of a Taiwan scenario – most Flanker airbases are situated within a reasonable distance of Taiwan. This is partly the result of the sales agreement with Russia, which stipulated that the aircraft could not be permanently based at locations in the proximity of China’s border with Russia.

There are 9 locations in the vicinity of Taiwan that currently base, or have based, PLA Flankers. For this analysis, one regiment (24 aircraft) is based at each. This does not account for China’s entire inventory, some of which would forward-deploy in a contingency. Some
Chinese aircraft will be positioned very close to the front, in order to intercept incoming attacks.\(^{295}\) Given the proximity of such intercept bases to an adversary, these bases would need to be relatively hardened. Airbases would also require adequate maintenance and other support capabilities. Two locations fit this description: PLA Fuzhou and PLA Changxing. These locations are both relatively close to Taiwan, 77 nautical miles and 376 nautical miles respectively. Both locations are in the most-hardened class of PLA airbases, featuring underground hangars and alert strips. Both locations also support, or have supported, the indigenous J-10. This aircraft, while in a different class than China’s Flankers, is a step up from older, 1960s-era fighters. Its presence indicates a more robust support infrastructure. A third location not currently hosting Flankers is postulated – PLA Folou on Hainan Do. While this location is somewhat removed from Taiwan, it is very hardened (including an underground hangar). One more regiment could join the regiment currently at PLA Hainan Do South in order to project power into the sea approaches to China’s southern ports.

\(^{295}\) The postulated disposition herein is consistent with scholarship on China’s likely air doctrine. The PLAAF would use a “light front, heavy rear” concept in order to limit the vulnerability of its aircraft. The “light front” aircraft may be particularly suited for the interception role, since they could respond quickly to incoming enemies. The airbases in the vicinity of Taiwan may limit China to a total campaign strength of 400-500 aircraft (not including long range aircraft and force enablers). The postulated Flanker beddown above would thus account for 50-60% of this campaign strength. It is also worth noting that PLAAF doctrine calls for outnumbering the enemy 4:1, and that the airspace in the Taiwan Strait could accommodate offensive operations of 168 aircraft at a time. You, The Armed Forces of China, pp. 129-131.
### Table 24

**Postulated Flanker Bases in a Contingency**

<table>
<thead>
<tr>
<th>Airbase</th>
<th>Base Hardening Features</th>
<th>Distance to Taiwan Strait (nm)</th>
<th>Currently Hosting Flankers</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA Fuzhou</td>
<td>Underground Shelter</td>
<td>77</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>PLA Zhangzhou</td>
<td>Hardened Aircraft Shelters</td>
<td>112</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLAN Luqiao</td>
<td>Revetments</td>
<td>245</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLA Quzhou</td>
<td>Revetments</td>
<td>250</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLA Nanchang</td>
<td>Revetments</td>
<td>329</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>Xiangtang</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLA Changxing</td>
<td>Underground shelter</td>
<td>376</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>PLA Wuhu</td>
<td>Hardened Aircraft Shelters</td>
<td>403</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLA Changsha Huanghua</td>
<td>Revetments</td>
<td>424</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLA Feidong</td>
<td>Underground shelter</td>
<td>469</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLA Suixi</td>
<td>Hardened Aircraft Shelters</td>
<td>541</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>PLA Folou</td>
<td>Underground shelter</td>
<td>668</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>PLA Hainan Do South</td>
<td>None</td>
<td>685</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>Reserve</td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
</tbody>
</table>

**Average Distance to CAP:** 381 nm

The table above shows the postulated contingency locations for China’s Flanker fleet. Nine airbases currently host Flankers. The three other postulated contingency locations are the most hardened bases available and have indications of more-developed support infrastructure. A number are held in reserve or at bases out of range of Taiwan.

**SAMPLE CALCULATION**

In order to compare like sorties with like sorties, the PLAAF/PLANAF calculations also use a simple mission profile: cruise to CAP, patrol 1.25 hrs, return to base. A sample calculation for PLA Feidong follows:

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296 Base hardening features based on author’s own survey of PLA airbase infrastructure and Kopp, “People’s Liberation Army Air Force and Naval Air Arm Airbase Infrastructure.”
PLA Feidong is 469 nautical miles removed from the midpoint of the Taiwan Strait. With a cruise speed of 480 ktas, transit time to the CAP location is

$$\frac{\text{distance}}{\text{cruisespeed}} = \frac{469\text{nm}}{480\text{ktas}} = .977\text{hrs}$$

Given a 1.25 hr on-station time, it follows that the total flight time is:

$$ .977\text{hrs} + 1.25\text{hrs} + .977\text{hrs} = 3.2\text{hrs}$$

As with the USAF calculations, to quantify the average maintenance required, we use a fixed maintenance time per sortie plus a variable maintenance time per flight hour. While PLAAF and PLANAF maintainers are certainly less-skilled than the USAF counterparts, the simpler aircraft design compensates, and we will not change expected maintenance parameters from those used in the USAF analysis. Together with taxiing and other preflight and postflight actions, this encompasses the total time on ground. While 3 hours is used for this factor for the USAF analysis, we shorten it to 2 hours here. This is to account for the smaller bases and consequent shorter taxiing times, the smaller number of aircraft at each base and the queuing inefficiencies thus avoided, and the simpler weaponizing characteristics of Russian-designed aircraft (designed for uneducated, conscript ground crews). Total ground time is thus:

$$\text{Ground actions + Fixed Maintenance + Variable Maintenance per Flt Hr} = 2\text{hrs} + 3.4\text{hrs} + .68(3.2\text{hrs}) = 7.58\text{hrs}$$

The average turnaround time for a mission plus the ground time before the next mission is simply

$$\text{Flight time + Ground time} = 3.2\text{hrs} + 7.58\text{hrs} = 10.78\text{hrs}$$
For 24 hour operations, this turnaround time is translated into a daily sortie rate and a steady-state CAP strength delivered from this base.

\[
\text{Sortie Rate} = \frac{24 \text{ hrs}}{\text{turnaround time}} = \frac{24\text{hrs}}{10.78\text{hrs}} = 2.22 \text{ sorties/day}
\]

\[
\text{CAP size} = \text{number aircraft} \times \text{sortie rate} \times \left(\frac{\text{loiter time}/24 \text{ hrs}}{24 \text{ hrs}}\right) = 2.78 \text{ Flankers on Station}
\]

This result is checked against a pilot flight time constraint, considered 12 hours before pilots are too burnt out to fly. For this constraint, we check 12 hours against a hot-pit turnaround time, or the flight time plus the 2 hour ground action time only (pilots can switch aircraft if too much maintenance is required). 2.22 3-hour sorties per day plus 2 hours ground time in between is less than 12 hours, so this scale of operations is not constrained by the amount of time a pilot can be flying.

These calculations were repeated for each postulated Flanker airbase. The table below shows the contribution to a notional steady-state CAP of a regiment of Flankers (Su-27s, Su-30s, or J-11s) at each airbase. The following posture shows 12 of 14 likely high-end fighter regiments dedicated to a Taiwan contingency, with 2 held in reserve. The PLA would not necessarily populate a steady-state CAP – certainly the actual campaign would be a good deal more varied and multi-faceted. However, this simplification allows us to compare Chinese sortie generation to USAF sortie generation on a daily basis, as well as explore the effect on Chinese sortie generation of attacks on these airbases.
Table 25
PLAAF Airbase Contributions to Sortie Generation

<table>
<thead>
<tr>
<th>Airbase</th>
<th>Base Hardening Features</th>
<th>Distance to Taiwan Strait (nm)</th>
<th>Sortie Rate</th>
<th>Contribution to CAP (aircraft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA Fuzhou</td>
<td>Underground Shelter</td>
<td>77</td>
<td>3.0</td>
<td>3.73</td>
</tr>
<tr>
<td>PLA Zhangzhou</td>
<td>Hardened Aircraft Shelters</td>
<td>112</td>
<td>2.9</td>
<td>3.62</td>
</tr>
<tr>
<td>PLAN Luquiao</td>
<td>Revetments</td>
<td>245</td>
<td>2.6</td>
<td>3.26</td>
</tr>
<tr>
<td>PLA Quzhou</td>
<td>Revetments</td>
<td>250</td>
<td>2.6</td>
<td>3.24</td>
</tr>
<tr>
<td>PLA Nanchang Xiantang</td>
<td>Revetments</td>
<td>329</td>
<td>2.4</td>
<td>3.06</td>
</tr>
<tr>
<td>PLA Changxing</td>
<td>Underground shelter</td>
<td>376</td>
<td>2.4</td>
<td>2.96</td>
</tr>
<tr>
<td>PLA Wuhu</td>
<td>Hardened Aircraft Shelters</td>
<td>403</td>
<td>2.3</td>
<td>2.91</td>
</tr>
<tr>
<td>PLA Changsha Huanghua</td>
<td>Revetments</td>
<td>424</td>
<td>2.3</td>
<td>2.87</td>
</tr>
<tr>
<td>PLA Feidong</td>
<td>Underground shelter</td>
<td>469</td>
<td>2.2</td>
<td>2.78</td>
</tr>
<tr>
<td>PLA Suixi</td>
<td>Hardened Aircraft Shelters</td>
<td>541</td>
<td>2.1</td>
<td>2.66</td>
</tr>
<tr>
<td>PLA Folou</td>
<td>Underground shelter</td>
<td>668</td>
<td>2.0</td>
<td>2.46</td>
</tr>
<tr>
<td>PLA Hainan Do South</td>
<td>None</td>
<td>685</td>
<td>2.0</td>
<td>2.44</td>
</tr>
</tbody>
</table>

Total CAP size: 36

These calculations indicate that the PLAAF and PLANAF could sustain a continuous CAP of roughly 36 aircraft from 12 regional airbases.
INTRODUCTION

One key observation this dissertation will explore is that, despite the likely combat dominance of USAF F-22s, USAF force enablers could be the “Achilles Heel” of our air operations. The PLA could take advantage of the vulnerability of these aircraft, by selectively attacking them and bypassing USAF fighters to the greatest extent possible. In order to defend the USAF ISR, C2, and refueling aircraft necessary to air operations, USAF fighters would be required to destroy the PLAAF aircraft that could attack them. We use the following model to judge their ability to do so.

FRAMEWORK

Here we postulate a 3-phase model that represents engagements and attrition in beyond-visual-range (BVR) combat, within-visual-range (WVR) combat, and the effects of PLA aircraft that manage to survive the first two phases. The model is represented pictorially below:
The representation of the model above showcases several key features that make its application to Flanker-F-22 combat representative. First, note that the attrition arrow in the BVR phase is directional. In BVR combat, we assume that F-22s cannot be engaged by Flankers due to their stealth airframe. We will relax this assumption when considering carrying external arms on the F-22, but in its clean configuration, this assumption is reasonable.

In contrast, once the F-22s have expended their AMRAAMS, their only armament is within-visual-range AIM-9s and a 20mm gun. To employ either of these weapons, the F-22s would find themselves well within the range that Flanker pilots could detect them visually or by infrared sensors. Thus, within visual range, F-22s are exposed to enemy fire, and the attrition calculation is performed on both red and blue aircraft. This will showcase that WVR combat is an especially deadly regime, and negates many of the F-22’s otherwise decisive advantages.

The end phase above describes the damage that surviving Flankers can cause after the defending F-22s have exhausted their armament. The
attrition calculation is then performed for the postulated targets of a Flanker raid: blue force enablers.

Attrition Calculation

The attrition calculations used follow an essentially Lanchestrian framework.

Most modern warfare simulations are, of course, stochastic, heterogeneous and complex; and will, if their myriad assumptions are correct, give much better predictions. But the Lanchester model, in contrast, has the virtues of simplicity: it makes strong simplifying assumptions, which nevertheless are (at least sometimes) close to being realizable, and the model brings out, through a subtle process, some stark conclusions.297

So while perhaps not offering the predictive power of one of the more detailed (and publicly unavailable) air combat modeling tools, the approach below is still useful in that it “provokes careful thought about the consequences of the conditions of engagement.”298

The following expressions describe the attrition that occurs in a single simultaneous engagement. They are simplifications of an approach developed by Lt Gen (ret.) Glenn Kent, adapted for a single clash of forces.299

Denote the initial number of red aircraft in an engagement as \( N_{Ri} \) and the number that survive this engagement as \( N_{Rs} \). The blue aircraft are denoted \( N_{Bi} \) and \( N_{Bs} \) respectively. The lethality of each aircraft is measured by the number of air-to-air missiles they carry, and the single-shot Pk each missile can achieve. The total kill potential of

298 Ibid.
299 The original approach was developed as a simple, credible way to assess the results of repeated engagements and cumulative attrition. The derivation is discussed in Kent et al., Thinking About America’s Defense: An Analytical Memoir, pp. 232-235.
each aircraft is simply the number of missiles carried multiplied by the Pk of each missile, and is denoted $KP_h$.

If both sides engage the other simultaneously, the number killed on one side is directly related to the total kill potential of the opposing aircraft. Thus, the number of red aircraft surviving an engagement is predicted by:

$$N_{R_i} = N_{R_i} \left(1 - e^{-\left(\frac{N_{R_i}}{KP_R}\right)}\right)$$

The number of blue aircraft surviving is predicted by:

$$N_{B_i} = N_{B_i} \left(1 - e^{-\left(\frac{N_{B_i}}{KP_B}\right)}\right)$$

But what of the aircraft that survive an engagement? Not all surviving aircraft will be fit to fight. Aircraft not killed outright will burn a large amount of fuel, and may need to quit the fight.\(^{300}\) The model will not only need to express the number of aircraft that survive each engagement phase, but also the number of aircraft that

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\(^{300}\) If the launches were not at point-blank range (which is reasonable because the F-22s will not wish to get too close and be detected), evasive maneuvers typically begin with a quick turn to put the missile behind the targeted aircraft and engaging full afterburner. The goal is to put as much distance as possible between the fighter and the incoming missile. If the missile was launched from far enough away (outside the “no-escape zone”), this maneuver will succeed in getting far enough away from the missile that the missile runs out of kinetic energy before it can intercept the fighter. If the pilot is not far enough away to simply outrun the missile, the target pilot will still profit from putting distance between himself and the missile. The further towards the outside of the missile’s effective range he can get, the greater the likelihood that his maneuvering will bleed sufficient energy from the missile to avoid a kill. Most missiles rely on kinetic energy left over from a relatively short rocket motor burn to maneuver in the terminal intercept stage. When the missile turns sharply to follow a maneuvering target, it will lose kinetic energy very rapidly. If a pilot can get to the outside of the missile’s kinetic envelope and maneuver a lot, he may force the missile to lose sufficient energy so that it will be unable to successfully intercept. Throughout the entire process, the pilot will be using whatever electronic or other countermeasures he can to confuse the missile and throw it off track.
survive unmolested and with sufficient fuel to continue to the next engagement phase. To do so, we recomputed the survival numbers given above, this time using a 1.0 $P_k$ for each air-to-air missile. The number that would survive this engagement is analogous to the number of aircraft that are not engaged by an adversary:

$$N_{B_i, \text{not engaged}} = N_{B_i} \left(1 - e^{-\frac{N_{PB_i}}{K P_k P_{sk=1}}}\right)$$

In each engagement phase, the initial number of PLAAF aircraft is taken from the number of aircraft that were not engaged in the previous phase. This number will be lower than the number of aircraft that survived the previous phase - this property accounts for fuel-burning evasive maneuvers. On the other hand, the F-22 has the ability to perform evasive maneuvers and re-engage. Thus, the number of F-22s at the start of any phase is simply the number that survived the last phase.

CONCLUSIONS

This model will allow the research to judge the effectiveness of USAF counter-air given the sortie generation calculations examined previously.
E. EFFECTIVENESS OF STANDOFF WEAPONS AGAINST PLA AIRBASE INFRASTRUCTURE

INTRODUCTION

Judging the effectiveness of attacking PLA airbase infrastructure requires a consideration of hardening and the effectiveness of standoff munitions in destroying those passive defenses and the aircraft in them. We judge that standoff weapons could not effectively destroy the more robust passive defenses (underground hangars), but would be effective against hardened aircraft shelters and revetments – which comprise the passive defenses at 9 of 12 postulated Flanker bases.

WEAPON EFFECTIVENESS AGAINST HARDENED AIRCRAFT SHELTERS

Destroying a hardened structure is a matter of applying sufficient overpressure to the concrete structure in order to cause a lethal failure in its structural integrity. For most targets we encounter, the overpressure required is commensurate with a near-miss by the typical weapons in the USAF inventory. This approach is consistent with targets like typical hardened aircraft shelters.

Some structures may be so hardened that applying lethal overpressure is practically impossible. Destroying these structures requires a different approach – hitting the target directly with a penetrating warhead. A penetrating warhead need not destroy the hardening features of a very hard target, but penetrates it well enough to deliver a smaller amount of explosive suitable to destroy whatever is inside. This approach may be necessary for deeply buried targets like C2 bunkers or very well-hardened targets like ICBM silos. However, this approach is unnecessary for the typical hardened aircraft shelter the USAF may encounter.

We now consider the prospects for standoff weapons to destroy hardened aircraft shelters, like the one pictured below, along with their contents.
For simplicity, we shall treat the hardened aircraft shelter as a circular target with a diameter equal to the smallest side of the rectangle pictured above. This simplification, shown below, is for ease of computation.

In order for the target pictured above to be destroyed, sufficient overpressure must be applied to cause catastrophic structural failure. Here we assume a lethal overpressure of 300 kilopascals (kPa),
consistent with reinforced concrete structures. Destroying aircraft and other soft targets do not require large overpressures. Thus it is safe to assume that if the shelter is destroyed, any aircraft in it will also be destroyed by the significant secondary fragmentation projectiles or cave-in that would be associated with a lethal hit on the HAS. The typical high-explosive warheads used in most bombs or standoff munitions produce very large overpressures close to the explosion, trailing off rapidly further away from the explosion. Below shows how the approximate overpressure of a 1,000-kg TNT charge declines with distance:

![Figure 55: Overpressure and Distance](image)

If we take a given weapon, the amount of high explosive associated with that weapon, and solve for the distance from the detonation that gives us a 300 kPa overpressure, we find the lethal radius of the weapon against a reinforced concrete structure. The table below shows the lethal radii and accuracies of a variety of USAF and USN standoff weapons:

---

Table 26
Standoff Weapons’ Lethal Radii and Accuracy\textsuperscript{302}

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Lethal Radius</th>
<th>Approximate CEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLAM</td>
<td>11m</td>
<td>3m with GPS, 6-10m with TERCOM and DSMAC</td>
</tr>
<tr>
<td>CALC M</td>
<td>17m</td>
<td>~5m</td>
</tr>
<tr>
<td>JASSM</td>
<td>8m</td>
<td>2.4-5m</td>
</tr>
<tr>
<td>JSOW</td>
<td>7m</td>
<td>~3m</td>
</tr>
</tbody>
</table>

A quick look at the chart above shows that the accuracy of most U.S. standoff weapons (expressed in circular error probable, or the distance from the aimpoint within which 50% of the weapons will land) is quite good compared to their lethal radius against a hardened aircraft shelter. Further, to destroy a hardened aircraft shelter, the weapons need not land within the lethal radius of the aimpoint. It must land within the lethal radius of the target, which is a less stringent condition if the target is suitably large. In order to destroy a hardened aircraft shelter, the weapon must land no further from the aimpoint than the weapon’s lethal radius plus the target’s radius. This is shown below.

\textsuperscript{302} Lethal radii calculated by author. CEP data from Jane’s Air Launched Weapons.
Figure 56
Lethal Radius of a CALCM vs. a HAS

The above figures shows that a CALCM must deliver its HE warhead within 27m of its aimpoint, the center of the HAS. This "critical accuracy" is simply the addition of the warhead’s lethal radius and the distance from the aimpoint to the edge of the HAS, the shape of which is simplified to be a circular target. Now that we have a "critical
accuracy” for our warhead, with a given CEP, we can find the probability that the HAS will be destroyed. The single-shot kill probability is given below:\(^{303}\)

\[
Pk = 1 - .5 \left( \frac{\text{critical radius}}{\text{CEP}} \right)^2
\]

For a CALCM with 5m CEP and a critical radius of 27m, the SSPk is roughly 1.0:

\[
Pk = 1 - .5 \left( \frac{27}{5} \right)^2 = 1 - .5^{29} \approx 1
\]

The table below shows the Pk associated with a single standoff weapon. If the lethal radii shown above are too optimistic, the probabilities of a direct hit are included. A direct hit on all but the hardest concrete structures are lethal – so this puts a solid lower bound on the probability of a kill.

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Pk, lethal overpressure</th>
<th>Pk if direct hit required</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLAM</td>
<td>.95-1</td>
<td>.5 if CEP=10m, .85 if CEP=6m, -1 if CEP=3m</td>
</tr>
<tr>
<td>CALCM</td>
<td>~1</td>
<td>.94</td>
</tr>
<tr>
<td>JASSM</td>
<td>~1</td>
<td>.94 if CEP=5m, -1 if CEP=2.4m</td>
</tr>
<tr>
<td>JSOW</td>
<td>~1</td>
<td>-1</td>
</tr>
</tbody>
</table>

We can see that a single U.S. standoff weapon is virtually assured to destroy the HAS target. However, the preceding analysis has not accounted for the likely attrition of standoff weapons by air defenses. The effectiveness of PLA air defenses is a wild card in this analysis.

**Attrition Due to Air Defenses**

China has a well-developed and modern integrated air defense system, including some of the most advanced of the Russian S-300 series

\(^{303}\) Qui Yong, “Study on the Threat of Precision Strike Conventional Weapons to Nuclear Weapons.”
of SAMs, considered comparable to the U.S. Patriot series. The latest, the S-300 PMU1 and S-300 PMU2, are reputed to have a Pk against a cruise missile of .4-.85.\textsuperscript{304} A stealthy or part-stealthy target may be at the lower end of the Pk range, with non-stealthy cruise missiles at the upper end. Even if the Pk noted previously is too optimistic, OSD reports that these systems have "limited ballistic and cruise missile defense capability."\textsuperscript{305} China has reportedly purchased 24 batteries of S-300 PMU1s and S-300 PMU2s, comprising 96 launchers.\textsuperscript{306} These 96 launchers could launch 384 interceptors before needing to reload, and can launch them 3 seconds apart. Even if a fraction were deployed to the Taiwan area, China has enough interceptors to significantly degrade a large scale attack by standoff weapons.\textsuperscript{307} It is likely, however, that the abilities of the acquisition, tracking, and fire control radars are the limiting factor in engaging cruise missiles. The ability to acquire, track, and fire is unknown, as is the low-altitude coverage of these radars. Their performance would be minimized by executing a large standoff attack at once - overwhelming air defense systems with a very large number of incoming weapons. Further, it is possible that the most advanced batteries would be prioritized to protect critical staging areas. Standoff weapons heading inland may be queued to other, lesser capable air defenses. On the other hand, PLA point defenses protecting key airbases may further degrade standoff weapons.\textsuperscript{308} And if the PLAAF could use its large inventory of obsolete aircraft to engage cruise

\textsuperscript{304} Carlo Kopp, “Almaz S-300/PT/PS/PMU/PMU-1/PMU-2, Almaz S-400 Triumph, Almaz S-400 Samoderzhets.”
\textsuperscript{305} OSD, Military Power of the People’s Republic of China 2008, p. 23.
\textsuperscript{306} “S-300 PMU Air Defence Missile System.” Sinodefence.
\textsuperscript{307} Carlo Kopp, “Almaz S-300/PT/PS/PMU/PMU-1/PMU-2, Almaz S-400 Triumph, Almaz S-400 Samoderzhets.”
\textsuperscript{308} Electromagnetic weapons need not physically destroy a standoff weapon (though some can). They must only jam or degrade electronics enough that guidance errors are large enough to cause the weapon to miss its target. One example is the Ranets-E high-powered microwave, with a plausible 7 nautical mile lethal range against military-standard electronics. See Carlo Kopp, “Directed Energy Weapons,” accessible at <http://www.ausairpower.net/dew-ebomb.html> for a full treatment.
missiles in ground-control-to-intercept missions, USAF options for attacking inland targets could be severely degraded.

Since the likely performance of Chinese air defenses is unknown, we approach the attrition of standoff weapons parametrically. The table below shows the probability of destroying a hardened aircraft shelter with one or two CALCMs for a range of degradation caused by air defenses.

<table>
<thead>
<tr>
<th>Attrition</th>
<th>One Weapon</th>
<th>Two Weapons</th>
<th>One Weapon</th>
<th>Two Weapons</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>.94</td>
<td>1</td>
</tr>
<tr>
<td>.1</td>
<td>.9</td>
<td>.99</td>
<td>.84</td>
<td>.98</td>
</tr>
<tr>
<td>.2</td>
<td>.8</td>
<td>.96</td>
<td>.75</td>
<td>.94</td>
</tr>
<tr>
<td>.3</td>
<td>.7</td>
<td>.91</td>
<td>.66</td>
<td>.88</td>
</tr>
<tr>
<td>.4</td>
<td>.6</td>
<td>.84</td>
<td>.56</td>
<td>.81</td>
</tr>
<tr>
<td>.5</td>
<td>.5</td>
<td>.75</td>
<td>.47</td>
<td>.72</td>
</tr>
</tbody>
</table>

It is immediately evident that, at current levels of weapon accuracy, attrition due to air defenses would account for virtually all missed HAS-sized targets. This would be true whether we use the overpressure criterion or the direct hit criterion (in the latter case, as long as attrition is at least .6 it will be a greater driver of missed targets than weapon accuracy). However, even with relatively high rates of attrition, high Pks could still be achieved by redundantly targeting shelters with two standoff weapons. As long as air defenses were not too effective or could be overwhelmed with large numbers of weapons, standoff munitions could be very effective in attacks against aircraft parked in HAS.

ATTACKING AREA TARGETS WITH SUBMUNITION WARHEADS

We have seen that hardening against an attack is an important feature of PLA airbases. Many bases are very hard, with underground shelters with redundant entrances, built into mountains. Others have hardened aircraft shelters in dispersed patterns and some degree of camouflage and concealment. Roughly half of the PLA fighter bases in
the Taiwan AO are hardened with revetments only. In the likely Flanker beddown that this analysis considers, 3 of 12 bases have revetments only and one other has no apparent hardening features. While revetments are good at minimizing damage from strafing attacks, unitary warheads, or secondary damage from burning aircraft – they are quite vulnerable to submunition warheads. This may be one reason why several bases with HAS seem to be upgraded revetment bases. As Stillion and Orletsky note, attacking soft targets parked in the open with submunitions is much more effective than attacking them with unitary warheads. They find that a 1,000 lb submunition warhead would cover roughly 8 times the area when compared to a unitary warhead of similar size.\textsuperscript{309}

While there are a variety of submunition weapons that can be delivered by fixed-wing aircraft, to this author’s knowledge submunitions have only slowly found their way into standoff weapons. Given their effectiveness, this may be a good area for future investment. One standoff weapon that does have a submunition warhead is the TLAM-D. Here we examine its effectiveness in attacking PLAAF and PLANAF infrastructure, specifically revetted parking areas.

TLAM-D carries 166 BLU-97 submunitions.\textsuperscript{310} Generally, the dispersal pattern of a cruise missile is rectangular, with the long side of the rectangle oriented with the azimuth of the weapon. The specific size of the dispersal footprint can be customized depending on the mission required (by varying the spin rate of the dispenser and the altitude at which the submunitions are dispensed). Here we calculate the optimum dispersal, which will be used for the calculations.

Stillion and Orletsky, in their analysis of the threat of submunition weapons, use a 20 foot lethal radius for 1 lb submunitions. The BLU-97 weighs roughly 3 lbs. If we use the cube rule to extrapolate its lethal radius, we arrive at a 29 foot lethal radius for the 3 lb

\textsuperscript{309} Stillion and Orletsky, \textit{Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks}, p. 12.
BLU-97 submunition. The lethal area of one submunition is simply $\pi (29 \text{ ft})^2$ or 2646 ft$^2$. If we extrapolate to the optimal footprint of 166 BLU-97 submunitions, the area covered will be approximately 440,000 ft$^2$, or a rectangle with dimensions 1,000 ft by 440 ft. Since the lethal area of each submunition is a circle, the actual lethal coverage of this area will be imperfect, but there is a high likelihood that within this lethal area, at least some piece of a target aircraft will be in this lethal footprint. Below we show the lethal footprint of this weapon and dispersal pattern:

Figure 58
TLAM-D Footprint on Revetted Dispersal Parking at Changsha Huanghua AB

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311 $20 \text{ ft} \times \left( \frac{3\text{ lbs}}{1\text{ lbs}} \right)^{\frac{1}{3}} = 29 \text{ ft}$ from Stillion and Orletsky, Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks, p. 13.

312 This is consistent with the medium dispersal footprint of a comparable weapon, the CBU-87 Gator, 880 ft. by 400 ft. Jane’s Air-Launched Weapons. Jane’s Information Group.
CONCLUSIONS

We can see that a single submunition warhead is capable of covering several dispersed aircraft revetments, and is a very high-leverage option for attacking aircraft not parked inside a reinforced concrete shelter.
REFERENCES


3. Automated Air Facility Information File.


42. Joint Munitions Effectiveness Manuals.


