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TECHNICAL REPORT

Wind Tunnel and Propulsion Test Facilities

Supporting Analyses to an Assessment of NASA's Capabilities to Serve National Needs

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Prepared for the National Aeronautics and Space Administration and the Office of the Secretary of Defense

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Summary

This technical report provides detailed data, observations, and conclusions from a one-year study from June 2002 through July 2003, examining the nation's wind tunnel and propulsion testing needs and the continuing place that the National Aeronautics and Space Administrations (NASA's) major wind tunnel (WT) and propulsion test (PT) facilities[2] have in serving those needs, identifying new investments needed and any excess capacities. The study focused on the needs for large (and thus more expensive to operate) test facilities as well as identified management issues facing NASA WT/PT facilities.

The details in this technical report support the major policy observations, conclusions, and recommendations contained in the companion monograph to the study (Antón et al., 2004[MG]).

Approach

Intensive and extensive interviews were conducted with personnel from NASA headquarters; NASA research centers at Ames (Moffett Field, Calif.), Glenn (Cleveland, Ohio), and Langley (Hampton, Va.), which own and manage NASA's WT/PT facilities; the staff of the Department of Defense's (DoD's) WT/PT facilities at the U.S. Air Force's Arnold Engineering and Development Center (AEDC, at Arnold AFB, Tenn.); selected domestic and foreign test facility owners and operators; U.S. government and service project officers with aeronautic programs; and officials in a number of leading aerospace companies with commercial, military, and space access interests and products.

We employed three semistructured interview protocols to provide advanced notice of the study needs and a level of consistency across the interviews. First, we used an interview protocol for our initial on-site visits and discussions with NASA programs, facility managers, and DoD users. Second, we developed a questionnaire to solicit projected utilization of NASA facilities. Finally, we used detailed supplementary questionnaires to solicit additional insights from aerospace vehicle designers in industry and the DoD. These questionnaires probed their strategic needs in each of the six WT/PT facility categories, to probe their pre-

[2] Throughout this report, we use the term "WT/PT facilities" to mean wind tunnel facilities and propulsion test facilities, that is, the type of NASA facilities we assessed. Since individual facilities within this designation can be either wind tunnel facilities, propulsion test facilities, or both, "WT/PT facilities" serves as a generic term to encompass them all. That being said, when a specific facility is talked about, for clarity, we refer to it as a proper name and, if necessary, include its function (e.g., Ames 12-Foot Pressure Wind Tunnel). As well, the term "test facilities" and "facilities" can be substituted to mean "WT/PT facilities." Of course, NASA owns and operates other types of test facilities outside of WT/PT facilities, but our conclusions and recommendations do not apply to them.

ferred facilities and acceptable/possible alternatives, the bases being used for facility selections (technical, business environment, etc.), their needs for new facilities, and their assessments of computational fluid dynamics' (CFD's) role in reducing WT/PT facility requirements.

In addition to the work of the RAND Corporation's resident research staff, the study employed a number of distinguished senior advisers and consultants to help analyze the data received and to augment the information based on their own expertise with various national and international facilities.

In addition, the analysis reviewed and benefited from numerous related studies conducted over the past several years.

Perspectives on the Approach

The analytic method used in the study to define needs does not rely on an explicit national strategy document for aeronautics in general, and for WT/PT facilities in particular, because it does not exist. Lacking such an explicit needs document, we examined what categories of aeronautic vehicles the United States is currently pursuing, plans to pursue, and will likely pursue based on strategic objectives and current vehicles in use.[3]

Also, as *enabling infrastructures*, WT/PT facility operations are not funded directly by specific line items in the NASA budget.[4] The study's determination of WT/PT facility needs and the resulting conclusions and recommendations are therefore not based on the federal budget process as a direct indicator of policy dictates of facility need. We determined WT/PT need by identifying what testing capabilities and facilities are required given current engineering needs, alternative approaches, and engineering cost/benefit trade-offs. This, of course, can lead to a bias in the findings because these assessments may be overly reflective of what the engineering field determines is important rather than what specific program managers are willing to spend on testing as a result of program budget constraints. Thus, when a needed facility is closed because of a lack of funding, there exists a disconnect between current funding and prudent engineering need, indicating that the commercial and federal budget processes may be out of step with the full cost associated with research and design of a particular vehicle class and signifying a lack of addressing long-term costs and benefits.

NASA's Ability to Support National WT/PT Facility Needs

Currently, NASA is mostly capable of providing effective quality support to its WT/PT test facility users within and outside NASA in the near term. Instances in which the agency cannot provide effective quality support lie mostly in specific gaps in their capabilities (which are mostly served by non-NASA facilities), in facility closures that endanger unique or important capabilities, and in management and financial support of strategically important facilities (as discussed below). There are important technical and management issues and potentially

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[3] Specific projects and plans were obtained from NASA, Office of Aerospace Technology (2001; 2002); NASA (2001a; 2003); National Aeronautics and Space Act of 1958; DoD (2000; 2002); FAA (2002); NRC (2001); Walker et al. (2002); NASA, Office of the Chief Financial Officer (n.d.); AFOSR (2002); and various DoD and commercial research and production plans.

[4] The *construction* of government WT/PT facilities are, however, very large expenditures requiring explicit congressional funding, and certain facilities, such as the National and Unitary facilities, have associated congressional directives regarding operation and intent.

adverse trends that NASA must begin to address more proactively now to stabilize the current situation and address long-term state-of-the-art testing requirements. If the agency does not act, there is a risk that serious deficiencies may emerge in the nation's aeronautics research and development (R&D) and test and evaluation (T&E) capabilities over the next 10 to 20 years. Proactive approaches to mitigate these potential problems have both management and technical dimensions.

What Management Issues Endanger NASA's Facilities?

Most importantly, NASA should identify shared support to keep its minimum set of facilities from collapsing financially as a result of variable utilization. It is important to note that the $125–130 million annual operating budgets for all NASA WT/PT facilities under study pale in significance to the national aerospace capabilities that they partially enable, including the federal investments in aerospace R&D of between $32 billion and $57 billion annually in the past decade and the military aircraft RDT&E funding alone of $4.5–7 billion a year in the same period.

Within NASA, the primary facility management problem relates to funding these test facilities operated by three autonomous centers in the face of declining R&D budgets. In the extreme case at Ames, the lack of resident aeronautics research programs combined with the center management's strategic focus toward information technology and away from ground test facilities have left the Ames WT/PT facilities without support beyond user testing fees and thus vulnerable to budgetary shortfalls when utilization falls. Two unique Ames facilities needed in the United States have already been mothballed as a result. The other NASA centers with WT/PT facilities—Glenn and Langley—rely heavily on resident research program taxes to cover low-utilization periods in their major test facilities, but center managers do not yet know whether full-cost recovery policies will nullify these funding sources.

If NASA management is not proactive in quickly providing financial support for such facilities beyond what is likely to be available from full-cost recovery pricing, the facilities will be in danger of financial collapse—some in the very near term. In the near term, this market-driven result may allow NASA to reallocate its resources to meet more pressing near-term needs, but the longer-term implications are less certain. In any event, given (1) the continuing need for the capabilities offered by these facilities for the RDT&E of aeronautic and space vehicles related to the general welfare and security of the United States, (2) the "right sizing" NASA has accomplished to date, (3) the indeterminate costs to decommission or eliminate these facilities, (4) the significant time and money that would be required to develop new replacement WT/PT facilities, and (5) the relatively modest resources required to sustain these facilities, care should be taken to balance near-term benefits against long-term risks. Options for obtaining alternative capabilities in lieu of certain facilities are discussed below, but even if these options are exercised, many facilities will remain unique and critical to meeting national needs.

The management solutions—once the problems and NASA's responsibilities for addressing them are well understood—hinge in most part on the dedication of financial resources to preserve important facilities through multiyear periods of low utilization. Management options in terms of who owns and who operates the facilities (e.g., government or private; NASA, DoD, or confederation; NASA-center-centric or centralized) will have vari-

ous pros and cons, but all will require a mechanism to stabilize and preserve capabilities needed in the long term through lean times. Key to subsequent analysis of these options is the collection and availability of the full costs of operating these facilities as well as the full costs associated with relying on alternative facilities. This report will help provide the motivation to address these policy, management, and cultural problems, ensuring the continued health of the nation's civil, military, and commercial aeronautics enterprises.

The study also identified a few second-order management issues and concepts that warrant mentioning for further analysis consideration: the importance of the test facility workforce, cross-training of facility crews, workforce outsourcing, and possible privatization options.

What Are the Nation's WT/PT Facility Needs?

The United States continues to need WT/PT facilities across all categories of need (strategic, research and development, and production), for all speed regimes and for specialty tests to advance aerospace research and to reduce the risk in developing aerospace vehicles. Utilization is not the overriding metric for determining the need for a particular type of facility. Despite declines in aerospace research and aerospace vehicle production rates in certain areas, the nation continues to pursue performance improvements in past aerospace vehicles types while exploring new vehicles and concepts, resulting in demands for empirical test simulation capabilities met by WT/PT facilities. CFD has made inroads in reducing *some* empirical test simulation capabilities, but CFD will not replace the need for test facilities for the foreseeable future. Flight testing complements but does not replace facility testing because of its high costs and instrumentation limitations.

How Well Do Existing NASA WT/PT Facilities Meet U.S. Needs?

NASA has 31 existing WT/PT facilities grouped by the six facility categories under study. Combining the agency's WT/PT facilities with the engineering design assessments for the vehicles the United States is pursuing now and in the future, *nearly all existing NASA facilities align with one or more need categories important to the country's ability to pursue aeronautic vehicles across NASA's roles of R&D, T&E, and strategic national interests.*

Most (26 of 31, or 84 percent) of NASA's facilities are technically competitive and effective with state-of-the-art requirements. However, there is room for improvement, especially in the high–Reynolds number subsonic category and in reducing the backlog of maintenance and repair (BMAR) across NASA's portfolio. There also has been discussion in the testing community for both large and small investments to improve NASA's test infrastructure, but it was difficult for our expert consultants and the user community to seriously consider large investment candidates given declining budgets, facility closures, and the failure of past efforts to obtain funding for facilities with improved capabilities. Selected challenges, though, such as hypersonics testing, will require additional research to develop viable facility concepts for future investment consideration.

What Are NASA'S Primary Facilities for Serving the Nation's Needs?

Twenty-nine of 31 NASA facilities play a primary role in serving one or more need categories important to the country's ability to pursue aeronautic vehicles across the agency's roles of R&D, T&E, and strategic national interests. Given recent facility closures (about one-third in the past two decades), NASA's set of test facilities (with two exceptions) is now nearly free of redundancy in type and capability *within* NASA.

The two existing backup NASA facilities are the Langley 12-Foot Subsonic Laboratory (a weakly competitive backup facility whose needs could be met by the Langley 14×22-Foot Atmospheric Subsonic Wind Tunnel) and the Langley 16-Foot Transonic Tunnel (a high-use, weakly competitive facility whose needs could be met by using air in the Langley National Transonic Facility or the Ames 11-Foot).

It should be noted that NASA is not the only source of WT/PT facilities serving national needs. The DoD, industry, and foreign facilities are being used and provide competing and sometimes unique capabilities. The technical capabilities of the primary non-NASA facilities that serve national needs are discussed in this report.