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February 2004 **SB-1020**

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ABSTRACTS

BOOKS

BOOK-020109 Cable Television: Franchising Considerations. W. S. Baer. 1974.

A comprehensive reference guide to cable television technology and issues of planning, franchising, and regulating cable systems, intended for local government officials and concerned citizens, as well as for college classes. The opening chapter explains how a cable system works and what new capacity is needed for additional channels, two-way communications, and new services. The FCC technical standards for franchising systems are presented and discussed. The next chapter discusses the franchising process in detail, with illustrations from existing and proposed franchises; the third covers technical considerations in franchising; and the final two chapters deal with citizen participation in planning and after the franchise is granted. Unlike the communications systems, cable television demands community participation and decisionmaking at the local level.

MONOGRAPH/REPORTS

MR-672-AF/A Mutual Interference in Fast-Frequency-Hopped, Multiple-Frequency-Shift-Keyed, Spread-Spectrum Communication Satellite Systems. E. Bedrosian. 1996.

This report presents the results of a theoretical analysis of a frequency-hopping, multiple-frequency-shift-keyed, spread-spectrum communication system using a nonprocessing communication satellite transponder. A large number of users are assumed to be hopping pseudo-randomly about the transponder passband in time synchronization and approximate frequency synchronization. The users are assumed to be free to hop independently with the result that they occasionally interfere with one another. Formulations are presented that permit assessment of the level of mutual interference, thereby facilitating the selection of system parameters that will maximize the communication throughput of the system.

MR-762-AF An Overview and Comparison of Demand Assignment Multiple Access (DAMA) Concepts for Satellite Communications Networks. P. M. Feldman. 1996.

Provides a broad survey of Demand Assignment Multiple Access (DAMA), a loosely-defined class of multiple-access techniques for allocation of satellite resources. DAMA schemes can be divided into two main classes: "Pure" DAMA, which involves circuit-switched resource allocation, is efficient for voice and for large file transfers, but inefficient for text messages and most short data transmissions. "Hybrid" DAMA schemes, which allocate resources using circuit switching in combination with packet switching or other techniques, address the limitations of pure DAMA in several different ways. The report explains the workings of these protocols and discusses implementation issues, including alternative control locales (fully centralized, fully distributed, and hierarchical). It examines vulnerabilites of these protocols (including unintentional interference, jamming of links, and destruction of critical nodes) and presents alternative mitigation strategies for these vulnerabilities, including some new design approaches. Performance results are included for many of the protocols, drawing on the published literature wherever possible and including some new performance results as well.

MR-1192-AF Employing Commercial Satellite Communications: Wideband Investment Options for the Department of Defense. T. Bonds, M. G. Mattock, T. Hamilton, C. A. Rhodes, M. L. Scheiern, P. M. Feldman, D. Frelinger, R. Uy, K. H. Henry, B. Zycher, T. T. Lai, D. Persselin. 2000.

Department of Defense decisions on the amount of communications it will own or lease will in turn affect U.S. Air Force investments in new communications satellites. The study team evaluated the effectiveness of commercial wideband satellites across several characteristics defined by the United States Space Command. The cost of buying or leasing commercial systems is then compared with the cost of buying military systems with commercial characteristics. The team found that there is a large projected gap between the military demand for communications and the capability expected from present, planned, and programmed systems. Whether or not the Department of Defense buys commercial-like systems, commercial leases provide a valuable way to increase capacity. Lease contracts should include the rights to switch transponders between beams as needed. Further, it may be more economical to make long-term commitments even if all of the capacity is not used than to underestimate demand and make up the shortfall with short-term service contracts. DoD should make its decisions based on demand for communications, the operational characteristics needed, and the ways in which commercial capabilities might aid the military.

MR-1402-AF Optimal Commercial Satellite Leasing Strategies. M. G. Mattock. 2002.

The Department of Defense needs far more satellite communications capacity than it owns and thus must lease satellite communications services. Communications planners can use the "rule of thumb" set forth in this study to aid in making efficient satellite leasing decisions in the face of uncertain demand for satellite services. It is a simple, graphical technique. Extensions to the basic model show how price uncertainty and the ability to salvage unused capacity change the appropriate amount of capacity to lease. A multiple-period version of the basic model shows how planners can consider the tradeoffs between long- and short-term leases when demand grows over time.

MR-1613-AF The Dynamics of Growth in Worldwide Satellite Communications Capacity. M. G. Mattock. 2002.

The Department of Defense (DoD) cannot afford to own all the satellite communications capacity it might need in all areas of the world. DoD planners estimate that they will need to provide about 16 Gigabits per second of bandwidth by 2010 to effectively support a joint-service operation. However, given current procurement plans, the DoD will own only one-eighth of this projected desired capacity. Therefore, for the foreseeable future, the DoD will need to buy at least some of its communications capacity from commercial vendors. An ability to understand what drives growth in worldwide satellite capacity and to predict capacity would be useful to military communications planners in making decisions in advance to purchase and lease communications capacity in various parts of the world. The author shows that there is a strong relationship between growth in total satellite communications capacity and economic growth, as measured by Gross Domestic Product. Adjustment to change is quite rapid; if there is an imbalance in the long-run equilibrium between supply and demand, on average 25 percent of the adjustment is made within one year, although there is some regional variation. The analysis indicates that the market can adjust swiftly to a surge in demand, and thus there may be little need to buy satellite capacity in advance simply to ensure that capacity will be there if needed.

REPORTS

R-0399-NASA Perturbations of a Synchronous Satellite. R. H. Frick, T. B. Garber. May 1962.

An investigation of the behavior of a synchronous (24-hour) satellite as affected by the triaxiality of the earth and the gravitational attractions due to the sun and moon. It is shown that, because of gravitational effects attributable to the out-of-roundness of the earth, station-keeping propulsion of as much as 17 ft/sec/yr would be required to establish a synchronous satellite at a given longitude above the earth's equator. The authors indicate that the perturbing effects of the sun and moon are (1) to displace the satellite within its orbital plane by a maximum of 45 miles and (2) to produce a rotation of the orbital plane away from the equatorial plane at a rate of about 0.85 deg/yr. If this latter effect needs to be corrected for proper operation of the system, it would require an additional propulsion of 150 ft/sec/yr.

R-415-NASA A Study of Passive Communication Satellites; a Report Prepared for the National Aeronautics and Space Administration. S. H. Reiger. February 1963.

A study of communication systems that use radio signals reflected from artificial earth satellites. Four main problem areas are examined: parameters affecting circuit capacity, the effect of orbital configuration on satellite visibility and continuity of service, systems trade-offs and costs, and comparisons with active repeater satellites. The conclusions are generally encouraging to the economic potential of passive reflector satellites, provided that a significant increase in reflecting cross section per unit weight over that of Echo I can be achieved and that higher power levels than are now generally available in the frequency range of interest are employed. Tolerable levels of service discontinuities appear to be possible, even when the number of satellites is not excessively large.

R-0454-NASA Orbital Regression of Synchronous Satellites Due to the Combined Gravitational Effects of the Sun, the Moon, and the Oblate Earth. R. H. Frick. August 1967.

Earth satellites in synchronous equatorial orbits are called "stationary," but over long periods their orbits do in fact vary. R-399-NASA analyzed the perturbations due to the gravitational effects of the sun and moon. This study extends the analysis to cover the effects of the sun, the moon, and the oblateness of the earth. The analysis applies to satellites in near-circular orbits at any inclination and with orbital radii less than 10 earth radii. The perturbed motion of satellites in various orbits is described as seen from inertial space and as seen from the rotating earth; by including higher-order terms, the analysis was extended to describe the regression of the moon. The ground trace of a synchronous altitude orbit at an angle to the reference plane is a figure eight that varies over time. For an orbit that is originally synchronous and equatorial, or "stationary," the ground trace starts as one point and gradually develops into a figure eight with crossing-point at the equator; its latitude excursion is 14 degrees 40 min after 26.6 years, after which the process is reversed. Fuel expenditure to prevent this regression is

proportional to the sine of twice the inclination angle to the reference plane. 186 pp. Ref.

R-0525-NASA Mapping by Computer Graphics: Satellite Antenna Coverage. N. C. Ostrander. October 1970.

Description of computer preparation of maps and overlays, especially for satellite antenna coverage. The examples were produced with an IBM 360/65 and S-C 4060 graphical plotter, using a data tape of 10,500 geographic points stored as 374 strings of alternate latitude and longitude values. This is adequate for maps of scale 1:40,000,000 (at which a world map is 40 in. wide). Rectilinear maps, azimuthal maps, and polar perspective maps (which show the earth as seen from a particular satellite position) are explained, with coordinate transformation equations for each. The most efficient coordinates for rectilinear maps are latitude and longitude; for azimuthal maps, direction cosines. With satellite rays nearly tangent to the earth, using geocentric coordinates and a spherical earth model, coordinates can cause errors of hundreds of miles. Latitude and longitude corrections for the geosynchronous distance of 6.166 earth radii are provided. 53 pp.

R-0538-NASA Acquisition Behavior of Some Adaptive Arrays. W. L. Doyle. October 1970.

The performance of two adaptive array schemes is analyzed. In scheme A, the desired signal is specified by a beam-forming vector; in scheme W, by a known pilot signal. In a stationary interference environment, if loop gains are high enough and the effective time constants are long enough, the weights in both systems will converge to values for which the output signal-to-interference ratio is maximum. One result of the analysis is a criterion for choosing loop gain and time constants that should be useful in designing an automatic gain control system, a practical necessity for both schemes. For the A scheme, the output signal-to-interference enhancement history during adaptation is found under the assumption that smoothing is sufficient to make weight fluctuations small and slow. For the W scheme, settling time varies inversely with pilot-to-interference power ratio. The results presented in this report are for the narrowband case. 36 pp. Ref.

R-0558-PR Transmission of Electromagnetic Waves Through Normal and Disturbed Ionospheres. H. G. Booker, C. M. Crain, E. C. Field. November 1970.

Calculations of expected total transmission attenuation are presented for earth-to-satellite paths in an ambient and a nominally disturbed ionosphere under both day and night conditions for frequencies from 10 to the minus 3rd power to 10 to the 10th power Hz. Height profiles of attenuation are given for frequencies from 1 Hz to 100 kHz. Results show that, under ambient conditions and for quasi-longitudinal propagation, the ionosphere is relatively transparent to electromagnetic waves having frequencies lower than about 10 kHz. For some classes of artificially or naturally disturbed ionospheres, frequencies lower than a few tens of Hz must be used if less than 30-dB transmission loss is to be avoided. Another possible scheme would be to use several satellites configured so as to maximize the probability that at least one satellite is transmitting under undisturbed ionospheric conditions. Part of the propagation path is thus assumed to be in the earth's ionosphere cavity. 34 pp. Ref.

R-0559-PR A Panoramic View of Ionospheric Reflection and Transmission Under Ambient and Disturbed Conditions. H. G. Booker, C. M. Crain, E. C. Field. November 1970.

The technical basis and results of a computer program using magneto-ionic equations to assess the effects of ambient and disturbed daytime and nighttime ionospheres on radio waves from microwave (10 GHz) to hydromagnetic (.001 Hz) frequencies. (Below about 100 Hz, the ray approach used gives only lower bounds for the transmission loss.) The disturbed conditions correspond to either a mild nuclear environment or a severe polar cap absorption event. Given the signal frequency, angle of incidence, and atmospheric ionization profile, the program calculates the real and imaginary components of the complex refractive index at all heights, the differential absorption at all heights, the reflection of nonpenetrating signal components, and the transmission of penetrating components, for either quasi-longitudinal or quasi-transverse transmissions. Results clearly show the existence of height-dependent pass bands, stop bands, and conduction bands in the ionosphere. Reflection levels and two-way reflection losses are also shown. 36 pp. Ref.

R-1463-NASA Orbit-Spectrum Sharing Between the Fixed-Satellite and Broadcasting-Satellite Services with Applications to 12 GHz Domestic Systems. E. E. Reinhart. May 1974.

Identifies and evaluates strategies for sharing the geostationary orbit in the band 11.7 and 12.2 GHz between domestic systems in the fixed-satellite and broadcasting-satellite services. The effectiveness of two distinct types of sharing strategies, referred to as spectrum division and orbit division, is determined for various deployments of selected baseline systems representing the two services and for various combinations of sharing tactics such as frequency interleaving, crossed-polarization operation, and crossed-beam operation. Effectiveness is measured by the "utilization factor," defined as the number of channels provided by the baseline systems when using an assigned share of the orbit-spectrum resource, relative to what they

could provide if given the entire resource. Computer simulation is used to verify the intra- and interservice interference compatibility of the assumed deployments. It is concluded that total utilization factors close to 100 percent can be achieved with both spectrum-division and properly chosen orbit-division strategies. Orbit-division strategies are to be preferred however because they permit a given total channel capacity to be achieved with fewer satellites and, for certain combinations of baseline systems, they yield a total utilization factor exceeding 100 percent. 253 pp. Ref.

R-1717-DNA The Role of the Magnetosphere in Satellite and Radio-Star Scintillation. H. G. Booker. March 1975.

A theory is developed to account for the scintillation phenomenon observed in equatorial regions when using communications satellites in the SHF band. The same theory is also used qualitatively to explain strong scintillations in the VHF band. Instead of confining irregularities to a narrow interval of height in the F region and assuming that they are strong, the alternative hypothesis is used that the irregularities are weak but extend from the F region upwards into the magnetosphere. It is suggested that the irregularities are field-aligned and extend at least up to an L shell of 1.3 and possibly up to 2 or more. 27 pp. Ref.

R-1936-RC A New Approach to Millimeter-Wave Communications. N. E. Feldman, S. J. Dudzinsky. April 1977.

An argument for the use of the millimeter wave band for military earth-satellite communication systems. Important advantages accruing from this use are larger bandwidths and narrower antenna beamwidths, which would reduce interference and ameliorate the frequency management problem while also improving covertness and resistance to jamming. However, millimeter waves are particularly susceptible to attenuation by rainfall. A new approach for designing around the rainfall problem is described and its benefits discussed. Outages caused by rainfall can be avoided by a variety of automatic switching schemes, by using techniques for increasing jam resistance, or by switching to a satellite in a different direction. The concept proposes switching only high-precedence traffic and only for the duration of the outage at the ground terminal. 20 pp. Ref.

R-1949-AF Geometric Performance of Pseudoranging Navigation Satellite Systems: A Computer Program. J. V. Lamar, L. N. Rowell, J. J. Mate. July 1977.

This report describes a computer program designed to analyze aspects of the geometric performance of pseudoranging navigation satellite (navsat) systems for users either on earth or in earth orbit. A navsat system includes a fleet of satellites, each with an accurate clock that transmits ephemeris, time, and other signals. These signals can be received by relatively small, inexpensive equipment, thus enabling the user to compute his position and time accurately. The NAVSTAR/Global Positioning System (GPS) is such a system, and its overall user accuracy can be broken down into two components which, when multiplied together, yield an estimate of the user's position and/or time accuracy. These two components are analyzed in this report. The first depends on the relative geometry among the navsats being employed and the user's location, and the second involves a determination of system errors. This report was prepared as part of a Project AIR FORCE study entitled "Space Warfare Issues," and should be of use to military and civilian defense analysts responsible for the design, use, and survivability of GPS and other U.S. space-related systems. 92 pp. Ref.

R-2275-DCA The Feasibility of Employing Frequencies Between 20 and 300 GHz for Earth-Satellite Communications Links. L. G. Mundie, N. E. Feldman. May 1978.

Develops a model for estimating in a new way the statistical distributions of signal attenuation, sky noise temperature, and total atmospheric-induced degradation in millimeter-wave link performance resulting from the presence of humidity, clouds, and rain in the atmosphere. The statistical distribution of system outages is then found for certain hypothetical commuications links using six frequencies and four elevation angles. To illustrate the compatibility of the communications equipment with small, mobile-user platforms, pointing and tacking, weight and power, radome considerations, and antenna options are treated. It is concluded that generally acceptable performance in the millimeter-wave frequency region can be obtained both for small, mobile users and for wide-band data relay users. (See also R-1936). 121 pp. Ref.

R-2532-JPL/NASA Control Networks for the Galilean Satellites: November 1979. M. E. Davies, T. A. Hauge, F. Y. Katayama, J. A. Roth. 1979.

First results on the development of the coordinate systems and control networks of the Galilean satellites of Jupiter. Pictures of the four satellites were taken as the two Voyager spacecraft approached Jupiter during March and July 1979, and nearly full coverage of the satellites was obtained by each flyby as the satellites rotated in front of the cameras. High-resolution mosaics of the satellite surfaces were obtained during closest encounter. Control nets of the Galilean satellites have been computed photogrammetrically and mean radii measured. The pictures in the control nets are identified, the coordinates of the control points are given, and identifications of some

of the control points are shown on figures. Improved results will emerge as more data are incorporated in the computations.

R-2936-ARPA The Flexural Behavior of PACSAT in Orbit. W. Sollfrey. 1983.

This report presents an analysis of the libration and vibration of a passive communications satellite known as PACSAT. It addresses the effects of various disturbing mechanical forces on verticality and straightness. Phenomena considered include orbital ellipticity, earth oblateness, solar and lunar gravity, radiation pressure, micrometeoroid impacts, and thermal bending effects. The last two are the most important. It is concluded that the flexural misbehavior of PACSAT in orbit is such that it is most improbable that the present design (unsupported linear array) can perform its communications functions.

R-3046-AF Techniques for the Analysis of Spectral and Orbital Congestion in Space Systems. A. L. Hiebert, W. Sollfrey. 1984.

This report is a compendium of the techniques available for analysis of spectral and orbital congestion in space systems. The expansion of signal transmissions and orbiting objects could severely affect the frequency spectrum allocations, orbit assignments, and related earth segments of space systems. The treatment of these problems requires a set of analytical procedures, computer programs to apply these procedures to specific configurations, and a database to provide inputs to the programs. The proposed Space System Data Base will consist of electromagnetic and operational characteristics of active and projected U.S. and international space systems including related earth and airborne segments. More than 20 analysis and computation codes are described, with the presentation pitched to an engineer's or user's level. The projected capabilities will provide an essential national resource for management decisionmaking and architectural planning on space-related programs.

R-3121-AF Commercial and Military Communication Satellite Acquisition Practices. G. K. Smith, J. P. Stucker, E. J. Simmons. 1985.

This study, by examining management practices and program outcomes associated with the acquisition of communication satellites by the Air Force and by the International Telecommunications Satellite Organization (INTELSAT), tests the contention that the commercial sector consistently manages acquisition programs better than the military. The study finds that the military and commercial programs are organized and managed in much the same way and that both produce well-functioning, useful spacecraft. Several significant differences in management practices and outcomes, however, suggest that the Air Force may be able to improve its acquisition activities. It concludes that, in carefully selected situations, there should be a place for the performance-oriented INTELSAT management practices.

R-3497-MF Issues in International Telecommunications: Government Regulation of Comsat. L. L. Johnson. 1987.

The question of government regulation of the Communications Satellite Corporation (Comsat) is paramount because of Comsat's market power in providing international satellite circuits to U.S. users. Comsat is the monopoly supplier of INTELSAT international satellite links. However, Comsat's satellite monopoly does not translate into a full monopoly of U.S.-overseas communications links, since undersea cable is a substitute. Taking into account advances in cable technology, and especially the introduction of fiber optics, Comsat's market power is being eroded and government regulation is becoming less important. However, the Federal Communications Commission (FCC) imposes circuit-loading restrictions that force AT&T to use a greater number of satellite circuits, essentially guaranteeing Comsat a portion of AT&T's traffic. This report discusses the history of the FCC's attempt to regulate Comsat, assesses FCC actions to reduce Comsat's market power, and evaluates the past effects of and future needs for such regulation.

R-4047-MF/RL Direct Broadcast Satellites: A Competitive Alternative to Cable Television? L. L. Johnson, D. R. Castleman, R. S. Leghorn. 1991.

This report presents an economic and engineering analysis of direct broadcast satellites' (DBS) prospects for competing with cable television systems in the United States and, hence, alleviating the need for extensive reregulation of cable. The authors examine relevant technologies, some implications of the technological advances that can reasonably be foreseen, and the comparative costs of DBS and cable systems. They also consider the prospects for second cable, wireless cable, satellite master antenna cable systems, and home satellite dish systems as alternatives to DBS systems to assess whether they hold more promise than DBS as competitors to cable. They then address a number of policy issues, including the effects on local broadcasting, whether cable operators should be permitted to buy into DBS systems, and the problems posed by access to programming. The findings suggest that high-power DBS systems are more likely than are the alternatives to provide widespread competition to cable. However, the outcome is dependent on several interrelated economic and technical factors, including the cost of earth terminals, the degree to which video compression reduces the per-channel cost of

satellites, and the level of operating expenses including program acquisition.

NOTES

N-1550-ARPA Concepts of Signal Acquisition and Processing for Use with a Passive Space Communication Array. J. C. Springett. 1980.

A passive communication satellite is attractive for relaying strategic messages between distant points under conditions where active communication satellite and other terrestrial links have been negated. This Note addresses two problems associated with efficient passive communication satellite use: (1) signal acquisition and (2) correction for array near-field signal degradation. A signal transfer model is developed for the satellite array, from which various fundamental properties are derived and used to assess the magnitude of the problems. Solutions are then proposed and evaluated with respect to practical implementations. Numerical examples are included, and the Note concludes with an outline for further work.

N-1780-ARPA PACSAT: A Passive Communication Satellite for Survivable Command and Control. E. Bedrosian. 1981.

Examines passive communication satellites as alternatives to active communication satellites in the hostile environment that may exist in the postattack period of a nuclear war. Inexpensive, survivable, and jam resistant, they offer an attractive low-data-rate capability. PACSAT is a proliferable candidate for this role. It consists of a long (about 1 km), gravity-gradient-stabilized array of small beads (about 1 cm in diameter) that reflects a narrow, conical, frequency-steerable beam back to the earth. The properties of PACSAT are presented and its performance in a representative system for the command and control of MX is evaluated.

N-2209-AF Improving MILSATCOM Acquisition Outcomes: Lease Versus Buy. P. M. Dinneen, T. H. Quinn. 1985.

Over the next decade, military satellite communication (MILSATCOM) systems will cost taxpayers billions of dollars. The magnitude of these costs and their distribution in the economy will be directly affected by whether public policymakers choose to lease or to buy these systems. This Note examines the arguments of leasing's opponents and proponents and the conclusions suggested by past leasing experiences. The analysis demonstrates that by far the most important consideration in deciding whether to lease or buy MILSATCOM systems is the cost of risk-bearing, an issue that has largely been ignored in the public debate: under a purchase, risks are borne by taxpayers, whereas under a lease, they are borne by the shareholders of defense contractors. On the basis of their analysis, the authors suggest that the Department of Defense consider soliciting bids that specify terms for both lease and buy options on MILSATCOM systems, since the competitive bidding system has the potential to provide a great deal of information important to policy decisions in risk-bearing.

N-2542-MF Excess Capacity in International Telecommunications: Poor Traffic Forecasting or What? L. L. Johnson. 1986.

Under international cooperative arrangements, governments and private firms have been remarkably successful in building worldwide systems of communications satellites and undersea cables. At the same time, the prospect of competitive entry by new firms offering satellite and cable services has triggered policy debate. Competition could foster new services and lower prices for some, while harming others. This Note examines the problem of excess capacity, which may grow because large international facilities are under construction, and because new market entrants are planning to invest in systems that compete with those of the established carriers. In particular, the author considers three reasons that common carriers and others have invested in a seemingly wasteful manner: (1) overoptimistic traffic forecasts, (2) market structure and regulatory policy, and (3) inefficient pricing of circuits.

N-2792-MF The Use of Excess Capacity in International Telecommunications to Deter Competitive Entry. L. L. Johnson. 1988.

This Note explores possibilities that owners of satellite and undersea cable facilities invest in excess capacity as a strategy to deter competitive entry by outsiders. The situation is illustrated by the controversy about the ground rules under which new satellite systems should be permitted to compete with INTELSAT. The study concludes that (1) issues of predatory pricing will persist in international markets, with anticompetitive use of excess capacity remaining a possibility; (2) even if excess capacity is being used to deter competition, competitive facilities are emerging; (3) the cost of excess capacity may be worth bearing if it helps to break monopolies held by postal, telegraph, and telephone administrations (PTTs); (4) INTELSAT and Comsat must be given pricing flexibility in a competitive market; (5) elimination of the Federal Communications Commission's ban on switched traffic on separate satellite systems might hasten liberalization by the PTTs; and (6) substitution of price cap regulation for rate-of-return regulation of AT&T might reduce any pressures for excessive investment from the U.S. side.

N-2848-DOS/RC The Future of INTELSAT in a Competitive Environment. L. L. Johnson. 1988.

The International Telecommunications Satellite Organization (INTELSAT) has been an important instrument of U.S. foreign policy because it has spread the benefits of advanced telecommunications technology to nations—especially developing nations—throughout the world. With the growing number of competing satellite systems, and the installation of transoceanic fiber optic cables, concerns have arisen about INTELSAT's ability to continue its role as global provider of service. This study projects and assesses possible financial futures faced by INTELSAT in this increasingly competitive environment, and suggests appropriate INTELSAT pricing strategies. The findings suggest that under a wide range of plausible assumptions INTELSAT will face financial stress because of competitive pressures. The author recommends that, in response, INTELSAT abandon its global cost averaging as the basis for setting prices and move to more flexible pricing that takes into account competitive alternatives in certain ocean basins and routes.

RAND MEMORANDA

RM-2640-ARPA Optimum Stress Design of a Rotating Wire Antenna. R. H. Frick. September 1960.

An investigation of a possible design for a wire antenna that is extended from a satellite and rotates about it to reflect intermittent radio signals between sending and receiving stations on the ground. In such a satellite, the longer the wire, the stronger the radio echo that can be reflected from it. Given the desired rotation rate (exerting a certain centrifugal force on the wire) and the tensile strength of the wire, this study determines the maximum possible length of the wire. It is indicated that for either steel or metallically coated glass fibers, lengths of 12,000 ft or more are possible. If two wires are used, extended in opposite directions, total lengths of more than 24,000 ft are possible. These lengths are adequate for useful communication purposes.

RM-2705-ARPA A Preliminary Investigation of the Motion of a Long, Flexible Wire in Orbit. T. B. Garber. 23 March 1961.

An examination of the stability of a long wire in orbit, particularly as it is affected by gravitational gradients. The study indicates that an antenna system of this type would probably be unstable. This condition could be fixed, but the modifications would impose additional problems, the most significant of which is a shorter useful life in orbit. A special case of a wire aligned with the vertical shows a relatively stable behavior, provided the initial disturbances are small. 54 pp.

RM-2709-NASA Communications Satellites: An Introductory Survey of Technology and Economic Promise. W. H. Meckling, S. H. Reiger. September 1960.

A discussion of the ability of communications satellite systems to provide broadband, long-distance communications at microwave frequencies without depending on intermediate ground-relay stations. Various alternative systems are identified: passive systems, low-orbit active systems, and twenty-four hour satellite systems. Part I of this study surveys the characteristics of these systems and assesses their advantages and disadvantages. Part II estimates the economic potential of communications satellites in terms of cost comparisons with other forms of telecommunications and in terms of demand prospects. A communications satellite system would very greatly increase the number of long-distance increase the number of long-distance channels available, and the cost per channel is therefore tied critically to the question of future demand for additional channels. (An abridgment of RM-2925.) 57 pp.

RM-2778-NASA Communications Satellites: Supplemental Information on the Cost Estimates Given in RM-2709-NASA. W. H. Meckling. June 1961.

Background information supplementing the cost estimates for communications satellites given in RM-2709-NASA, "Communications Satellites: An Introductory Survey of Technology and Economic Promise." This Memorandum presents equations for computing costs per voice channel. Their application is explained for communications satellites, submarine cables, and microwave relay systems. 21 pp.

RM-2787-NASA Power-Bandwidth Tradeoffs for Feedback FM Systems: A Comparison with Pulse-Code-Modulation. E. Bedrosian. 1961.

A discussion of the use of negative feedback in FM (frequency-modulation) receivers to lower the signal level required for a given quality of performance. This technique could be important in the design of communications satellites because it minimizes the amount of transmitter power that must be placed in orbit. The author shows that the use of large amounts of feedback can reduce the transmitter power required by about 8 db (compared with a conventional FM system designed to minimize transmitter power) and by about 5 db (compared with a pulse-code-modulation system of comparable performance). The penalty paid for this improvement is an increase in the bandwidth occupied: The feedback system requires a radio channel about twice as wide as that used by either of the other two systems.

RM-2845-NASA Communications Satellites and Telephone Rates: Problems of Government Regulation. L. L. Johnson. 1961.

An examination of the telephone tollrate changes likely to follow the cost reductions made possible by the use of satellite communications systems. Only a tenuous relationship exists today between costs and rates for particular telephone services because of the nature of government regulatory practices, and because the telephone firm itself has an interest in pricing its services in a manner somewhat divorced from considerations of cost. Given the continuation of these practices, the study concludes that the effect of satellite communications on rates will be highly uncertain—an undesirable situation on both political and economic grounds. Suggestions are made about changes in regulation that would contribute toward a more desirable outcome.

RM-2921-NASA Satellite Charge-Up as a Means of Maintaining the Shape of Echo-Type Satellites in the Outer Van Allen Belt. R. O. Hundley. December 1961.

An examination of the possibility of Echo-type satellites maintaining their shape by acquiring negative electrostatic potentials in the outer Van Allen belt. Based on calculations of the repulsive force of these potentials versus the principal forces tending to cause satellite collapse, it is concluded that the charge-up method of maintaining satellite shape would probably not be useful for opaque satellites. For partially transparent balloon satellites at the center of the outer Van Allen belt, the method might be useful part of the time. For partially transparent satellites at the lower edge of the outer Van Allen belt, the method would be, at best, marginally useful. 34 pp.

RM-2925-NASA Communication Satellites and Public Policy: An Introductory Report. B. H. Klein, J. M. Goldsen, L. S. Lipson, W. H. Meckling, F. T. Moore, S. H. Reiger. 1961.

An outline of the problems of public policy raised by the development of satellite-communication techniques. The study surveys satellite technology as of mid-1960, analyzes outstanding technical problems, estimates the probable costs of some of the more promising systems, and analyzes future demand for overseas telecommunications under likely cost conditions and use possibilities. The authors also indicate areas of federal responsibility, both international and domestic, including the problem of frequency allocation. (Abridgment published as RM-2709.)

RM-2971-NASA Foreign Participation in Communication Satellite Systems: The Implications of the Federal Communications Act. M. L. Schwartz. December 1961.

Discusses the problems of foreign participation in a communication satellite system from the standpoints of policy formulation and agreement negotiation. This Memorandum assesses the legal eligibility of foreign nations to share in the ownership or control of a U.S.-licensed communication satellite operation. 58 pp.

RM-3185-NASA On the Motion of Echo I-Type Earth Satellites. L. N. Rowell, M. C. Smith, W. L. Sibley. May 1962.

A study to determine whether balloon-type communication satellites remain sufficiently stable to be economically competitive with other means of communication. During certain orientations of Echo I, perturbing forces due to solar radiation pressure and air drag operate in the same direction, so the decrease in perigee altitude is rapid. At other times, the opposing forces counteract each other. Examples give uses of these effects to influence orbital altitude and, consequently, satellite lifetime.

RM-3255-NASA An Optimal Orbital Control Process for a 24-Hour Communication Satellite. J. A. Burkhart, F. T. Smith. July 1962.

A discussion of the modification of the orbit of a 24-hour communication satellite to increase the useful orbital lifetime and to minimize the amount of fuel consumed during the process. The computation of the orbit transfer by the method of dynamic programming is described, and numerical results are presented that relate the weight of fuel consumed to useful orbital lifetime. The effects of errors in the orbit-determination process and the adjustment of system parameters on the numerical results are discussed.

RM-3274-NASA Effect of Micrometeorite Collisions on Spherical Wire-Mesh Passive Reflectors. E. Bedrosian. August 1962.

An investigation of the possible effects of micrometeorites in reducing the useful lifetime of a spherical, wire-mesh, passive-reflector communication satellite. Theoretical conditions are postulated under which a wire composing part of the mesh might be severed by a hypervelocity collision with a micrometeorite. This criterion, taken with the known flux of micrometeorites, is used to compute the probability that such collisions will degrade the electrical performance of such a reflector. It is concluded that they will not significantly affect its useful lifetime. 21 pp.

RM-3296-NASA Stability of a Cloud of Orbiting Dipoles. R. H. Frick. August 1962.

A method for producing an orbiting cloud of dipoles that could be used as a very effective passive satellite reflector. The reflecting area of the dipole cloud would be considerably greater than that obtained from a balloon satellite of equal mass. The method described for producing the cloud represents a modification of and an extension to the Westford experiment. 40 pp.

PAPERS

P-2647 Economic Problems of Establishing a Communications Satellite System. L. L. Johnson. October 1962.

Testimony given before the Subcommittee on Monopoly of the Senate Select Committee on Small Business, August 3, 1961, on the economic problems of establishing a communications satellite system. The economic benefits of voice-channel cost reductions from satellite use might reduce overseas toll-telephone rates and lower delay times in completing calls. The government should consider giving the first satellite firm its franchise with the understanding that monopoly rights are not conferred in perpetuity, but rather that additional franchises may later be given to competing firms. A combination of satellite and conventional communication links appears to be superior from a cost standpoint to a system containing a large number of ground stations. If the United States attaches high priority to having a large number of ground stations around the world, it must consider the increased risk of being the second nation to have an operational satellite system. 9 pp.

P-3027 Estimates of Communication Satellite System Degradation Due to Rain. N. E. Feldman. October 1964.

Rain influences the performance of a communication satellite link not only by attenuating the signal, but also by adding thermal noise to the other sources of sky noise. This paper (1) combines all sources of noise, including rain, as a function of frequency and elevation angle; and (2) presents estimates of time distributions of degradation of the down link due to rain for various system noise temperatures in the absence of rain. 34 pp. Bibliog.

P-3639 Some Implications of New Communications Technologies for National Security in the 1970s. L. L. Johnson. September 1967.

An overview of technological development in communications, with emphasis on the potential contribution of communication satellites to national security. Satellite systems can be used for necessary communication in international crises and for command and control in wartime. Broader implications discussed relate to open and closed societies, centralization and decentralization of decisionmaking functions, and the process of bargaining and negotiation. 24 pp.

P-5311 Orbit-Spectrum Sharing Between the Fixed-Satellite and Broadcasting-Satellite Services at 12 GHz. E. E. Reinhart. October 1974.

Identifies and evaluates strategies for sharing the geostationary orbit in the band 11.7 to 12.2 GHz between domestic systems in the fixed-satellite and broadcasting-satellite services. Effectiveness of two types of sharing strategies—spectrum division and orbit division—is determined for various deployments of selected baseline systems representing the two services and for various combinations of sharing tactics, such as frequency interleaving, cross-polarization operation, and crossed-beam operation. Effectiveness is measured by the "utilization factor," i.e., the number of channels provided by the baseline systems when using an assigned share of the orbit-spectrum resource, relative to what they could provide if given the entire resource. Conclusions are: Total utilization factors close to 100 percent can be achieved with both spectrum-division and properly chosen orbit-division strategies, but the latter are preferred because they permit a given total channel capacity to be achieved with fewer satellites and, for certain combinations of baseline systems, they yield a total utilization factor exceeding 100 percent. 6 pp.

P-5935 Modeling System Performance Throughout the Millimeter Wave Band. L. G. Mundie. 1978.

A model has been evolved which estimates the statistical distribution of the two weather-related factors which limit system performance. These factors are the signal attenuation and the related sky noise temperature. From these inputs the total performance degradation due to atmospheric effects is determined. Frequencies of 21.2, 31, 48, 101, 152 and 265 GHz and elevation angles of 10, 30, 45, and 90 degrees are treated. The model is developed for one particular location (Washington, D.C.), but could be extended to any location where suitable weather statistics are available.

P-7836 Remote Sensing and Global Competitiveness. S. Pace. 1993.

These remarks were given at the First Annual Symposium on Coupling Technology to National Needs as part of a panel on "Visualization and Communication: Overhead Imagery." Based on the author's involvement with remote sensing policy while at the Department of Commerce from 1990 to 1993, the paper provides a brief overview of U.S. policy and legislation affecting remote sensing, discusses recent developments, and identifies continuing issues for

commercial ventures. Sample issues include operating licenses, export controls, government as a customer, and strategic partnerships.

DRAFT

DRU-683-CTI Emerging Global Positioning System (GPS) Applications in a Global Information Infrastructure. 1994.

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