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Although lagging the initial schedule, it now sees first spacecraft being assembled

Nimbus spacecraft development

BY HARRY PRESS and JACKSON V. MICHAELS, NASA Goddard Space Flight Center

The Nimbus project is the follow-on to Tiros in the NASA meteorological satellite program. As the initial step in the development of a global meteorological satellite system, the Nimbus concept specifically calls for worldwide coverage on a regular basis and an increased payload capability to provide a platform for an increased number of sensors. Preliminary design of the Nimbus spacecraft was completed in 1960.[1,2]

More than two years have now elapsed, and it will be appropriate to describe the approach used in the system, to present a brief history of the development, and to assess achievements to date in the light of the original design objectives.

Nimbus' basic objective has been to develop a meteorological satellite system that will provide basic data on worldwide atmospheric processes for real-time use in weather forecasting and for research studies. To accomplish this objective, the Nimbus system was conceived as an earth-stabilized satellite in a near-polar orbit, as shown on page 44, capable of full global observation on a daily basis, with the earth's rotational movement providing longitudinal coverage and the orbital motion of the spacecraft providing latitudinal coverage. The initial choice of an 80-deg retrograde 600-n. mi. orbit, with a local-noon equatorial crossing, ideally suits these requirements, permitting optimum picture-exposure times and keeping the orbital plane in the earth–sun line for prolonged periods. As the illustration shows, this arrangement also simplifies the mechanical design of the solar paddles, because it requires only one axis of rotation for orientation with the sun. The polar orbit allows readout of data from all orbits by two ground stations, to be located in Fairbanks, Alaska, and Eastern Canada.

An additional objective, fundamental in the approach to the Nimbus system, was a spacecraft design of inherent flexibility that would permit evolution of the individual subsystems and sensors with minimum interface and redesign problems. The Nimbus spacecraft, shown on page 43, includes a completely separable control system and a sensory ring incorporating a large number of standard-size bays to accept individual subsystem modules of fixed size and standard interface requirements. Contained within the sensory ring are the power-supply electronics and battery modules and the clock-command and pulse-code-modulated (PCM) telemetry subsystems. These three subsystems, together with the controls package and the solar paddles, compose the minimum Nimbus spacecraft ensemble.

Performance of the Nimbus spacecraft is monitored by a 672-channel telemetry subsystem having still further growth potential. The original spacecraft configuration contained fully redundant Advanced Vidicon Camera Subsystems (AVCS), consisting of six cameras, two four-track tape recorders, and two S-band transmitters and antennas, plus associated electronics and control circuitry. The cameras use 1-in. vidicons with 800-line resolution, providing picture resolutions of 1.5 mi. at the corners and 0.5 mi. at the zenith, at an altitude of 600 n. mi.

In addition, the configuration contained fully redundant Automatic Picture Transmission Subsystems (APTS), similar in performance to the AVCS, but designed for continuous real-time picture transmission, rather than for storage and data readout to a central data-acquisition station. Every 208 sec along the orbit path during daylight hours, APTS will provide pictures to relatively inexpensive ground stations equipped with facsimile recording devices, thus effectively bringing broad real-time cloud-cover data to almost every element of the worldwide meteorological community.

Remaining subsystems of the original configuration were a five-channel Medium-Resolution Infrared Radiometer (MRIR), similar to that flown in the Tiros spacecraft, and a High-Resolution Infrared Radiometer (HRIR), designed to be the night-time cloud-cover complement of AVCS and responsive to the 3.4- to 4.2-micron region of the infrared spectrum. Included, too, was a Low-Resolution Infrared Radiometer (LRIR), designed to examine the earth's heat budget. Inability to achieve required performance goals caused the elimination of

HARRY PRESS
is Nimbus Project Manager at Goddard SFC. Previously head of the OARP Structures and Operating Problems Div. at NASA Headquarters, his background includes 12 years of research on aircraft and missile structural loads at Langley Research Center, three years as head of its Gust Loads Branch, and, earlier, three years as a USAF weather officer and instructor in meteorology at NYU.

JACKSON V. MICHAELS
Numbus Spacecraft Systems Manager at Goddard, previously headed the Technical Staff of the Army Signal R&D Labs' Astro Electronics Div., engaged in technical planning for Courier, Score, Tiros, and Advent. He has taught courses in space technology, and is co-author of the book "Introduction to Space Communication Systems," to be published by McGraw-Hill.

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the LRIR subsystem early in the program.

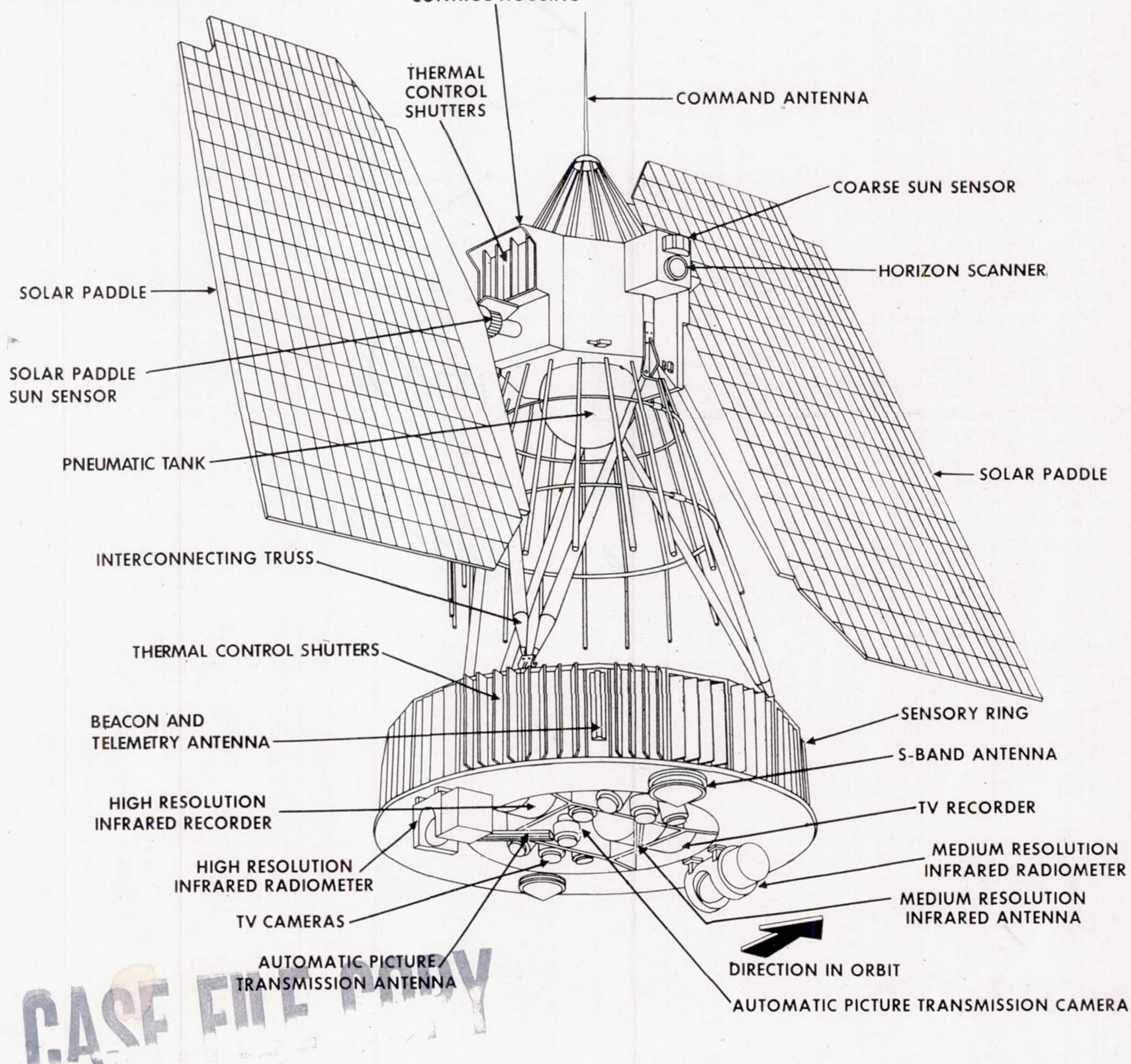
The equally basic design objective of long life (six months in orbit) dictated the use of conservative design practices, extensive subsystem redundancy, and intensive subsystem and spacecraft qualification. A high margin of safety is generally secured during prototype development by qualification under conditions more severe than the actual launch and space environments. Flight hardware is qualified under the nearest possible simulation of the anticipated flight levels. Before subsystem integration, all thermal and mechanical system conclusions are validated by checking and testing full-scale thermal and mechanical models to prototype qualification levels.

With the completion of the initial design in 1960, there was defined a basic management approach to the system development, consisting of the government (specifically, NASA's Goddard Space Flight Center) assuming the role of prime contractor and system manager, with the responsibility for selecting industrial contractors to develop and fabricate the subsystems, and for providing technical and managerial direction of the subsystem development efforts. A project manager and four system managers (for the spacecraft, launch vehicle, data-acquisition, and data-utilization systems) were appointed to head the over-all project effort.

The modular aspect of the Nimbus concept allowed development of the subsystems to proceed concurrently with preparatory spacecraft development. Substantial advanced mechanical and thermal analyses, and corroboration of these analyses by full-scale model testing, were conducted with good results. However, the price paid for this flexibility has been the need for close supervision of subsystem development and tight control of interfaces.

In late 1960 and early 1961, individual contracts were let for parallel development of each of the subsystems, calling for detailed design, breadboard development, and prototype and flight-hardware construction. The contracts also covered extensive subsystem environmental qualification testing in regard to humidity, acceleration, vibration, and vacuum-thermal conditions.

NIMBUS SPACECRAFT



In addition to development of the individual subsystems, a contract was let for integration and testing of the complete spacecraft. This contract covered construction of the basic spacecraft housing structure, integration of the various subsystems into a full prototype and into flight spacecraft, over-all spacecraft system performance testing, and, finally, a vigorous spacecraft environmental-qualification testing program. Noteworthy is the development of a system which simulates, within the confines of a vacuum chamber, the operation of the spacecraft in orbit (see page 46). During vacuum-thermal qualification, the full Nimbus spacecraft floats on a film of air, tracking an artificial horizon with communication only by radio to the checkout equipment outside the chamber.

Initial plans called for the sequential development and construction of the initial flight spacecraft at six-month intervals, in what was envisioned as an orderly research and development activity. It was thought that the first spacecraft development cycle would require about 1 1/2 years, one year being allotted to subsystem development and 6–9 months to spacecraft integration and qualification. This time schedule turned out to be overly optimistic.

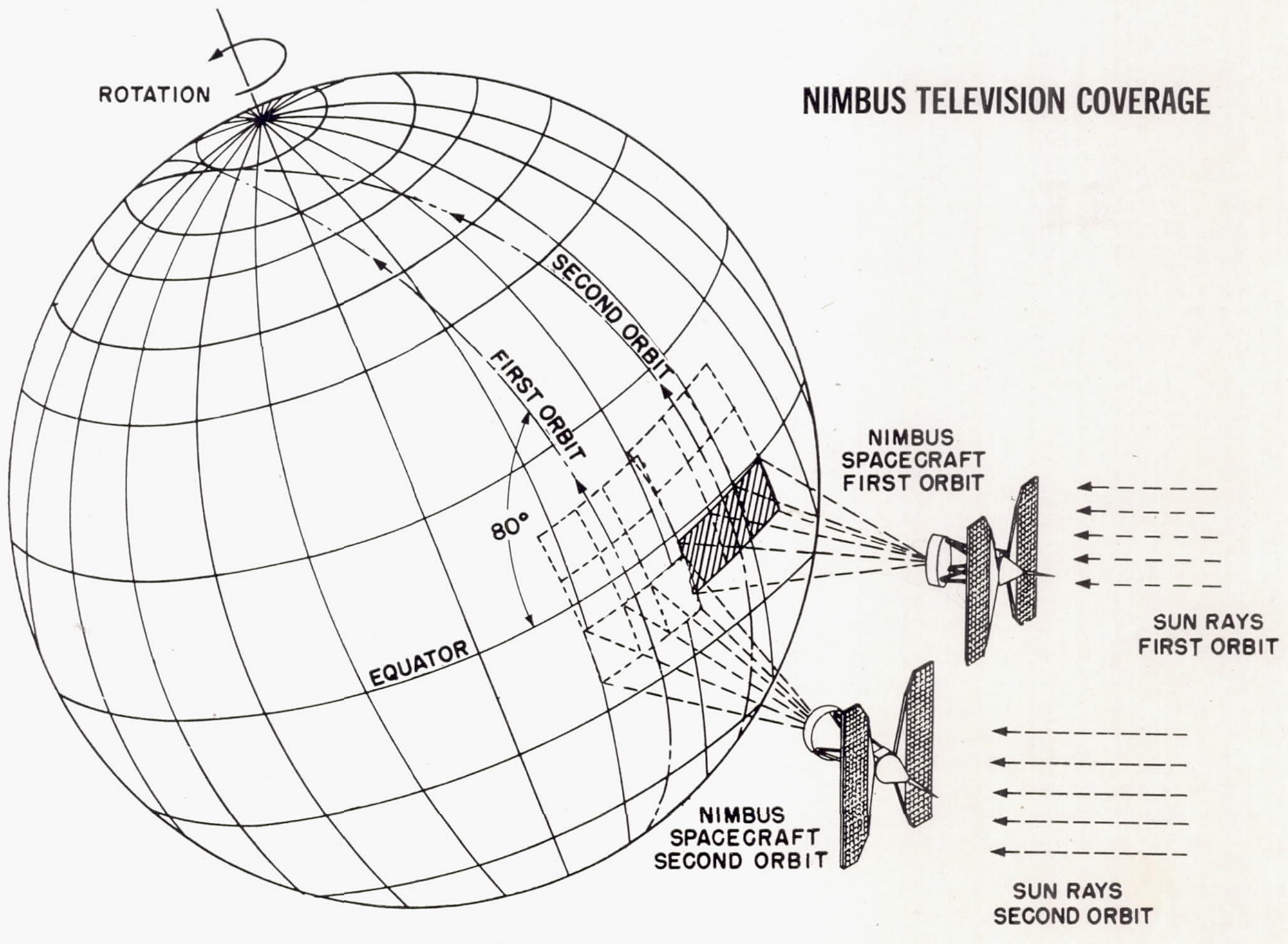
The progress of Nimbus was accelerated rapidly when, in May 1961, the President presented a special message to Congress requesting an accelerated Nimbus program "to give us at the earliest possible time a satellite system for worldwide weather observation." Later that year, the Congress appropriated additional funds to the Weather Bureau to implement this objective. This new requirement essentially resulted in revisions and accelerations of the program aimed at an earlier worldwide operational capability. Additional spacecraft funds were included, as well as funds for additional ground stations, in order to assure a worldwide weather-observation capability. NASA, working in conjunction with the Weather Bureau, moved rapidly to supplement the existing R&D program to meet this objective.

Nimbus spacecraft development has encountered significant delays due to technical difficulties in the development of a number of major subsystems. Although these delays have been time-consuming and expensive, the problems were not insurmountable. The table on page 45 compares major system performance achievements with the initial design objectives. In most cases design objectives have been attained. The achievement of an AVCS with the desired resolution and high linearity (1/2%), using a wideband frequency-multiplexed system, is a significant accomplishment in storage systems. The development of APTS is also considered a major advance in real-time meteorological systems. In two cases—stabilization accuracy and the HRIR resolution—some compromise of design values was found necessary, but this should not seriously affect early flight missions, and the design values will be subject to later improvement.

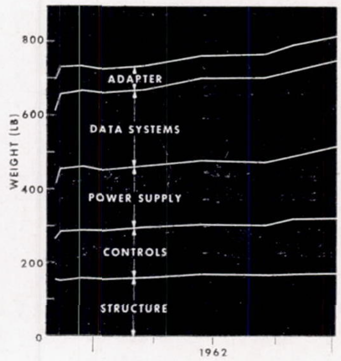
All major subsystems have been built and fully qualified in prototype hardware, with two exceptions. Flight hardware also nears completion. The two exceptions are the stabilization and control subsystem and the solar paddles. Each of these has posed serious development problems.

In the control subsystem, a major redesign of the infrared horizon-scanning system used for attitude sensing was required to achieve reliable attitude data. The redesigned system has been built and has performed satisfactorily in tests, although sensor ac-

NIMBUS TELEVISION COVERAGE



NIMBUS 'A' WEIGHT HISTORY



PRESENT NIMBUS PERFORMANCE

	DESIGN OBJECTIVE	ACHIEVEMENT
WEIGHT	650 LB	750 LB
STAB. ACCURACY	± 1%	± 2%
POWER (MAX)	450 WATTS	400 WATTS
AVCS (RES)	½ MILE	½ MILE
PCM TELEMETRY	672 CHANNELS	672 CHANNELS
HRIR (RES)	2 MILES	5 MILES
MRIR (RES)	30 MILES	30 MILES
COMMANDS	128	128
APTS (RES)	1½ MILE	1½ MILE

NIMBUS AND TIROS COMPARED

	TIROS	NIMBUS
GEOMETRY	PILLBOX	DUMBBELL
WEIGHT (lb)	300	650
ORBITAL ALTITUDE (nautical miles)	380	600
ORBITAL INCLINATION	48° EQUATORIAL	80° POLAR, RETROGRADE
STABILIZATION	SPIN-STABILIZED	3-AXES EARTH ORIENTED
EARTH COVERAGE	10 TO 25%	100%
CAMERA RESOLUTION	500 LINES/FRAME	800 LINES/FRAME
TV RESOLUTION (miles)	1	1/2
MAXIMUM POWER AVAILABLE (watts)	20	400
IR SENSORS (resolution, miles)	MRIR (30)	MRIR (30) HRIR (5)

curacy does not yet provide the full pointing accuracy desired.

Development and construction of the solar paddles was also seriously delayed by a decision in late 1962 to change from the initial p-on-n solar cells to more-radiation-resistant n-on-p cells. This decision arose from the unexpected creation of an artificial radiation belt at Nimbus flight altitude by a high-altitude nuclear-explosion test in mid-1962. New and satisfactory cells are now being procured and integrated into Nimbus.

As mentioned previously, a major weight problem was encountered in spacecraft development. The design objective was a weight of 650 lb for the spacecraft, to permit compatibility with the medium-sized Thor-Agena booster. Although every effort was made to meet this objective, it was readily apparent by mid-1961 that the full Nimbus spacecraft with the planned redundancy would exceed design weight by a substantial amount, and would exceed the launch vehicle capability. It was accordingly concluded that the early development flights would not include the desired redundancies.

A modified Nimbus configuration was defined in late 1961 and programmed for the early flights. Subsequent subsystem development gave rise to additional weight increases, so that the basic spacecraft now weighs about 750 lb, but can still be launched by the Thor-Agena to an altitude of 500 n. mi.

In the present configuration, the spacecraft contains one three-camera AVCS, one single-camera APTS, and the HRIR, in addition to the minimum spacecraft elements described previously. Although the original payload goals appear optimistic in light of subsequent developments, the weight history at the top indicates that the sensory subsystems account for about 20% of the total weight, constituting a reasonable payload efficiency. Structure, which includes wiring harnesses, thermal controls, and antennas, is less than 25% of the payload. Later flights, which plan to incorporate full redundancy, will require a launch vehicle of increased capability.

In parallel with the spacecraft development, the Nimbus project is also developing a Command and Data Acquisition (CDA) system to provide near real-time readout of data from all orbits. As indicated earlier, full orbital coverage can be achieved with two high latitude stations, one at Fairbanks and the other in Eastern Canada. The construction of the Fairbanks station is well underway and the station should be operational by early fall in ample time for the initial flight. The station will include an 85-ft tracking antenna with auto-track capability as well as an extensive data processing system for data evaluation and data transmission over wide band microwave links to the GSFC and to the Weather Bureau. The sensory data will thus be available for direct application to weather forecasts. The construction of the second CDA station in Eastern Canada has been delayed. Meanwhile, NASA plans to use the antenna system at Rosman, N.C., as a second and backup station for the initial flight.

In summary, the development of the Nimbus spacecraft has proceeded at a slower pace than initially planned, but the technical problems are now almost completely solved and the first flight spacecraft assembly is underway. A great deal has been learned about the technical problems implicit in a meteorological satellite with the capability of Nimbus, and the problems inherent in the management approach taken. Initial flights should prove the validity of Nimbus design concepts and our ability to realize them in flight systems. This flight experience, moreover, should provide the decisive tests on which to base the growth of a national meteorological satellite system.

References

1. Press, H. and Stampfl, R., "Nimbus Spacecraft System," *Aerospace Engineering*, July 1962.
2. Stampfl, R. A., "The Nimbus Spacecraft and Its Communication System," NASA Technical Note D-1422, Jan. 1963. ••