



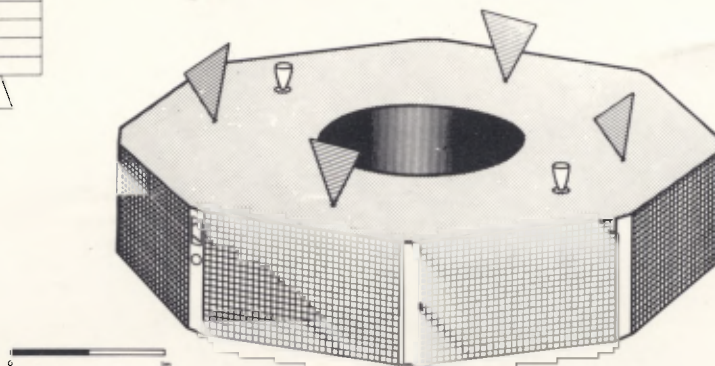
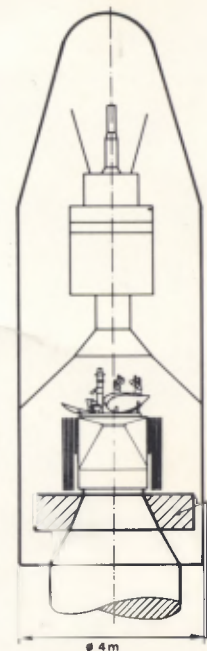
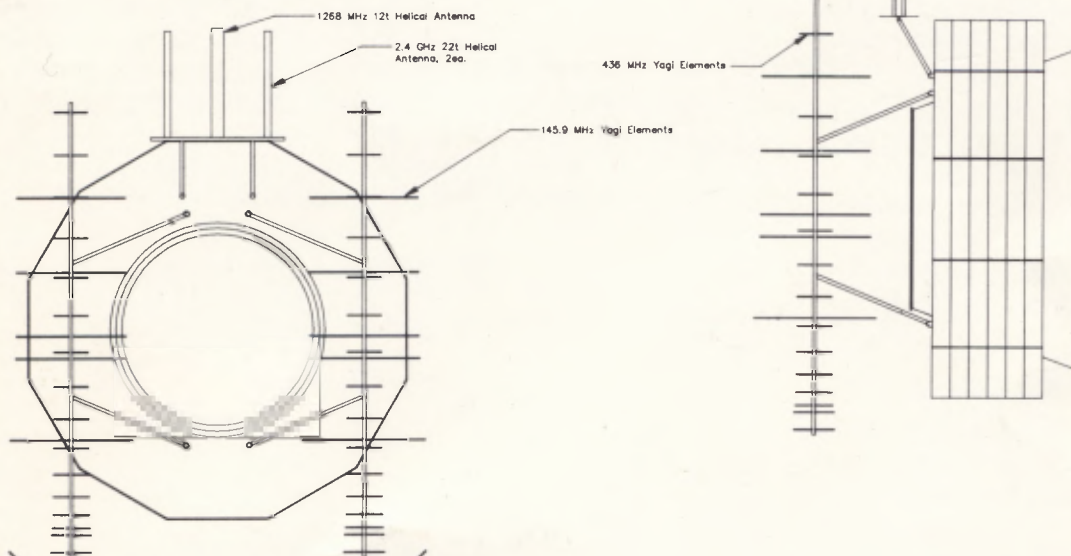
AMSAT-NA Technical Journal

Volume 1, No. 2

Winter, 1987-88

Spaceframe Design Considerations for the Phase IV Satellite

Page 16



The Radio Links to Phase III-D—An Initial System Concept

Page 23

AMSAT-NA Technical Journal

AMSAT-NA Technical Journal is a publication of the Radio Amateur Satellite Corporation of North America, AMSAT-NA. *AMSAT-NA Technical Journal* publishes papers reporting original work and significant findings in the fields of low-cost satellite design, construction, and operation, space communications, space sciences and related social value issues.

Contributions to *AMSAT-NA Technical Journal* are unrefereed working papers. Their content should be considered the personal opinion of the authors rather than organizational (company, any AMSAT group, etc.) unless otherwise noted. Readers who may wish to express their opinion on the content of an article may contact the author or the editor will forward their comments to the author.

The Radio Amateur Satellite Corporation of North America, AMSAT-NA Board of Directors

John Browning, W6SP, Chairman
Dr. Thomas A. Clark, W3IWI
Jan King, W3GEY
Dr. Robert McGwier, N4HY
Vern Riportella, WA2LQQ
William Tynan, W3XO
Harry Yoneda, JA1ANG

AMSAT-NA Officers

Vern Riportella, WA2LQQ, President
Dr. John Champa, K8OCL, Executive Vice President
Jan King, W3GEY, Vice President, Engineering
Ralph Wallio, W0RPK, Vice President, Operations
William Tynan, W3XO, Vice President,
Manned Space Projects
Doug Loughmiller, K05I, Vice President,
Field Operations
Art Feller, KB4ZJ, Treasurer
Martha Saragovitz, Secretary

Headquarters and Staff

AMSAT-NA
850 Sligo Ave., Suite 601
Silver Spring, MD 20910
Phone (301)-589-6062

Martha Saragovitz, Director of Administration

AMSAT-NA Technical Journal is published twice yearly in June and November for \$10 by AMSAT, 850 Sligo Ave., Suite 601, Silver Spring, MD 20910. POSTMASTER: Send address changes to *AMSAT-NA Technical Journal*, 850 Sligo Ave., Suite 601, Silver Spring, MD 20910.

Copyright © 1988 by AMSAT-NA, The Radio Amateur Satellite Corporation of North America. Contents may be reproduced without specific prior permission provided proper credit is given to the author and source and copies are sent to AMSAT-NA, the Editor, and the author. AMSAT is a registered trademark.

Information for Authors and Editorial Address

Prospective authors are invited to submit articles for future issues of *AMSAT-NA Technical Journal*. Papers must contain a one paragraph abstract and be limited to ten pages (where possible) including graphs, tables and references. Preference will be given to unpublished works. Papers of general interest will be accepted for reprinting if the author includes documentation of the conditions of the original publisher for reprinting.

Material for publication should be submitted both in hardcopy form and as a text file on diskette. Any 5¼ inch format is acceptable provided the format is clearly indicated and all special character sequences used by word processors have been deleted from the text file. Figures should be drawn in a manner suitable for publication and larger than the size in which they will appear when published.

All material submitted to the Editor will be considered for publication unless otherwise requested. No material will be returned. A contribution to *AMSAT-NA Technical Journal* is welcomed from any person with an interest in the amateur radio space program. Contributions should be sent to:

Robert J. Diersing, N5AHD, Editor
AMSAT-NA Technical Journal
Corpus Christi State University
6300 Ocean Drive
Corpus Christi, TX 78412
(512)-991-6810 ext. 476

Table of Contents

<i>Editorial</i>	Robert J. Diersing, N5AHD	2
<i>Spacecraft Technology Trends in the Amateur Satellite Service</i>	Dick Jansson, WD4FAB	3
<i>The Propulsion Systems of the Phase-III Series Satellites</i>	Richard L. Daniels, W4PUJ	9
<i>Spaceframe Design Considerations for the Phase IV Satellite</i>	Dick Jansson, WD4FAB	16
<i>The Radio Links to Phase III-D: An Initial System Concept</i>	Dr. Karl Meinzer, DJ4ZC	23
<i>Some Thoughts on RUDAK Traffic Control</i>	Hanspeter Kuhlen, DK1YQ	27
<i>PSK Interface for the TNC1</i>	Peter Gulzow, DB20S	30
<i>NUSAT-I's "Layered" Protection Software Design</i>	Chris Williams, WA3PSD	32
<i>A Method for Evaluating Antennas for a Low Earth Orbit Mission</i>	Courtney Duncan, N5BF	36
<i>The Integrated Housekeeping Unit</i>	Gordon Hardman, KE3D	42
<i>Keplerian Elements for Various Satellites</i>		8, 22, 46

On the Cover

The cover shows possible realizations for two amateur radio satellites of the future. In the upper left is the AMSAT-NA Phase IV satellite and antenna system. Phase IV will be a geostationary satellite.

On the lower right is the Phase III-D satellite proposed

by AMSAT-DL and its position as a payload on an Ariane launcher. Phase III-D will have an elliptical orbit like Phase III-C.

Articles about the design of both of these satellites appear in this issue.

Editorial

by

Robert J. Diersing, N5AHD

Associate Professor of Computer Science
Corpus Christi State University

This second issue of *AMSAT-NA Technical Journal* realizes one of the goals President Riportella and I agreed should be accomplished by its publication—that of informing the satellite user of the variety of engineering and construction activities required to produce an operational amateur radio satellite. In this issue we bring you information about spacecraft yet to be built: Phase IV, Phase 3D, and PTSE-H; and those that have already been built: Phase 3C, Phase 3B, and NUSAT I.

Amateur radio satellite enthusiasts are anxiously awaiting the launch of AMSAT Phase 3C in early summer. Two articles describe subsystems used in Phase 3B and, with various improvements, in Phase 3C: “The Integrated Housekeeping Unit — A Method of Telemetry, Command and Control for Small Spacecraft” by Gordon Hardman and “The Propulsion Systems of the Phase III Series Satellites” by Dick Daniels. Both of these papers were presented at the First Utah State University Conference on Small Satellites held on October 7, 1987.

From a user interest viewpoint, the AMSAT-DL RUDAK experiment on Phase 3C should prove to be very popular. Two articles related to RUDAK appear in this issue: “Some Thoughts on RUDAK Traffic Control” by Hanspeter Kuhlen and “PSK Interface for the TAPR TNC-1” by Peter Gulzow. These articles have appeared in the *AMSAT-DL Journal*.

The satellite design category is adequately represented in this issue as well. “Spaceframe Design Considerations for the Phase IV Satellite” by Dick Jansson describes various factors of spaceframe design, especially those affecting thermal design for the Phase IV geostationary satellite proposed by AMSAT-NA. “The Radio Links of Phase III-D: An Initial System Concept” by Karl Meinzer shows how AMSAT-DL intends to improve the Phase III series to serve a larger user community. Finally, we have “A Method for Evaluating Antennas for a Low Earth Orbit Mission” by Courtney Duncan showing factors being considered during the design of PTSE-H (also called HOUSAT).

Two more articles round out this issue and each is important for different reasons. First, “Spacecraft Technology Trends in the Amateur Satellite Service” by Dick Jansson serves to remind us of the history and accomplishments associated with our chosen specialty within Amateur Radio. This paper was also presented at the Utah State University conference mentioned earlier and as a result served to present those accomplishments to a wider segment of space technology professionals. Second, “NUSAT I’s ‘Layered’ Protection Software Design” by Chris Williams is important because we have not seen much information in print about small satellite projects outside the amateur radio community. Chris’s article also presents a different philosophy of user access to the spacecraft onboard computer.

In any all-volunteer effort such as the production of this journal, it is always important to acknowledge those who contributed to the project. I would like to express my appreciation to those authors who prepared articles especially for this issue: Dick Jansson, Chris Williams, and Courtney Duncan. Dick Jansson also provided the drawings for Phase IV shown on the cover. Thanks are again due AMSAT-DL for providing English translations for the articles reprinted from the *AMSAT-DL Journal*.

On the production side of the house are my secretary Maggie Hernandez and my wife Julie doing some of the word processing and proofreading. Typesetting and graphic design were once again done by John Stalmach, CCSU Office of Public Information. I was grateful to receive the Publications Achievement Award at the last AMSAT-NA annual meeting. However, it should have been given to those people mentioned here and in the previous editorial.

The next issue of *AMSAT-NA Technical Journal* will be published this summer. With all of the design and construction activities now in progress I hope I will be overwhelmed with articles.

Spacecraft Technology Trends in the Amateur Satellite Service

by Dick Jansson, WD4FAB
Phase IV Study Team

(Presented at the 1st. Utah State University
Conference on Small Satellites, October 7, 1987)

ABSTRACT

Small communications satellites have been employed by the Amateur Radio community for over twenty five years. These satellites have been used by tens of thousands of radio amateurs for recreation, education and scientific investigation. The Amateur satellite program today is international in scope with nine countries having contributed space flight hardware to the overall effort. A total of 14 satellites have been fabricated in the OSCAR series. Another 11 have been constructed in other programs resulting in a total of 25 satellites and 29 spacecraft-years of orbital experience.

This paper will address the history of the spacecraft developed for the Amateur Satellite Service with emphasis on technology trends in the program. Particular emphasis will be placed upon the mass, cost, system capability and construction phase duration for each of the fourteen satellites of the OSCAR series.

The Amateur satellite program has not simply adopted technology from other larger satellite programs. In many cases entirely unique design concepts were employed, required because of the small size of the spacecraft, the very limited power available or the limitation of fiscal resources. The development of high efficiency linear communications transponders and the design of highly integrated command, control and telemetry equipment are two examples. For many years these techniques have been of little value to designers of larger spacecraft, who have alternatives. With the new interest in lightweight satellites at low cost, these techniques may take on renewed applicability.

Introduction

Small communications satellites have been employed by the Amateur Radio community for over twenty-five years. These satellites have been used by tens of thousands of radio amateurs for recreation, education and scientific investigation. In recognition of the potential value of these activities, the International Telecommunications Union established, in 1971, the Amateur Satellite Service; a separate service from the Amateur Radio Service but with common objectives. The Federal Communications Commission has followed suit in its Rules and Regulations, Part 97, Subpart H. Spectrum has been allocated to the Amateur Satellite Service throughout the HF, VHF, UHF and microwave bands.

The Amateur satellite program today is international in scope with nine countries having contributed space

flight hardware to the overall effort. A total of 25 satellites have been fabricated in the world-wide Amateur Satellite program resulting in 29 spacecraft-years of orbital experience to date. One of the satellites failed to achieve orbit due to a launch vehicle failure and one awaits launch on the new European ARIANE-4.

This paper will address the history of the spacecraft developed for the Amateur Satellite Service with emphasis on technology trends in the program. Particular emphasis will be placed upon the mass, cost, system capability and construction phase duration for each of the fourteen satellites of the OSCAR series. The Amateur satellite program has not simply adopted technology from other larger satellite programs. In many cases entirely unique design concepts were employed, required because of the small size of the spacecraft, the very limited power available or the limitation of fiscal resources.

The development of high efficiency linear communications transponders and the design of highly integrated command, control and telemetry equipment are two examples of these technologies. For many years these techniques have been of little value to designers of larger spacecraft, who have alternative technology options. With the new interest in lightweight satellites at low cost, these techniques may take on renewed applicability.

In the process of developing spacecraft of this nature, new strategies for environmental testing, component selection, materials selection, system redundancy and program management had to be developed. Some of these new strategies are driven by fiscal restraints, while others by manpower resources, these approaches differ significantly from conventional spacecraft programs.

Historical Background

The launch of the first artificial satellite, Sputnik I, excited the imaginations of a great many people around this globe. The world of Amateur Radio ("ham" radio) is one that historically has attracted devotees that have been filled with curiosity, investigation and "imagineering," all to create new methods and applications in the realm of radio communications. These two statements, seemingly unconnected, converged about two years following the launch of Sputnik I, with a group of California amateurs, incorporated as Project OSCAR, initiating a program to build an OSCAR (Orbital Satellite Carrying Amateur Radio). After two years of their efforts, OSCAR I was launched on 12 December

1961 as a "piggy-back" secondary payload aboard an Air Force Thor-Agena launch vehicle carrying the Discovery XXXVI payload. These events have been suitably documented by Davidoff and others, starting with the visions of a magazine writer.[1]

Oscar I was but the first of some 25 satellites, built by radio amateurs around the world, that have either been orbited or are planned to be launched. Fig. 1 chronicles the relentless pursuit of radio amateurs toward achieving highly reliable global communications with complete freedom from the effects of ionospheric propagation phenomena. The 40 years of past and future OSCAR activity shown provide the background of our experience and lay the plan for our future expectations. Fig. 2 is a log of the operating history of each of these satellites, presented with a logarithmic abscissa covering time from 1.2 days to 31.7 years. Note also that there are eleven Russian radio amateur satellites that have been launched, the RS and Iskra series. As we have very little information on their construction and properties, further efforts to include them in this discussion is not practical.

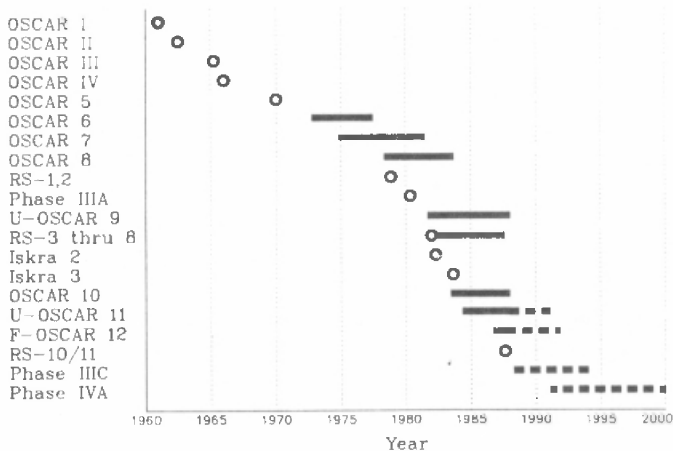


Figure 1. Amateur Satellite Flight History

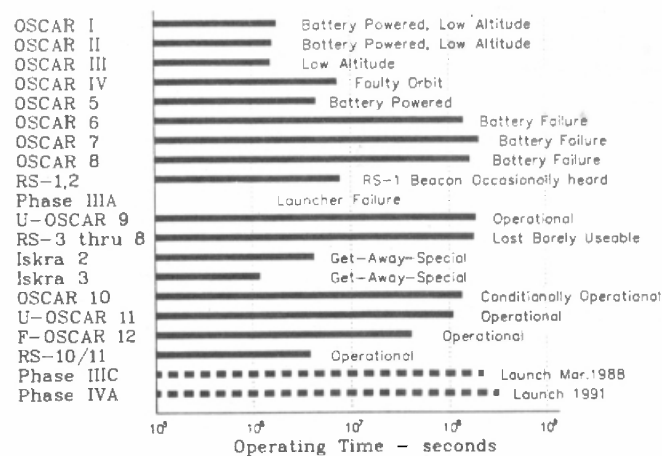


Figure 2. Amateur Satellite Flight Log

AMSAT

Starting with OSCAR 5, a new organization was formed for the exploitation of amateur radio satellites. Called

the Radio Amateur Satellite Corporation, it is more commonly known as AMSAT, a successor to Project OSCAR in launching amateur satellites.

AMSAT has grown into an international organization and spun off a number of affiliate organizations in other countries. Most of the work done on amateur satellites in the last fifteen years has been done as international efforts, with one or more national groups defining the basic spacecraft. This consortium has also provided the systems design and control and defined the subsystem interfaces. Substantial design flexibility exists in the subsystems, as long as their interface requirements are met, and the execution of these subsystems have been delegated to even other groups. Phase III satellites provide a good example of this process.

The central consortium has been between (as we know it now) AMSAT-NA (AMSAT North America) and our West German colleagues, AMSAT-DL. Subsystems have been fabricated by Bulgarians, Japanese, Australians, South Africans and other national AMSAT groups. Even the spaceframe assembly in suburban Washington, DC, looked like a small United Nations.

This decentralized, all volunteer army does have its drawbacks in managing a program, but the dividends are that the program can draw on the talents of highly capable and motivated persons. Many of these volunteers are aerospace professionals on their own right, but the aura of an amateur spacecraft attracts them to contribute their time and talents to the program.

OSCAR Program Phases

The many spacecraft constructed by radio amateurs can be roughly classified by their intended function into four Phases. Phase I designs comprise low earth orbit (LEO), short lifetime beacon satellites, such as OSCARs I, II, III, 5 and Iskra 1 and 2. Phase II designs are also LEO (but not as low an altitude), long lifetime satellites with active transponders and experiments, such as OSCARs 6, 7, and 8, UoSAT OSCARs 9 & 11 and RS 1-11. Phase III satellites are designed to function in elliptical Molnia-type orbits at high altitudes, for long lifetimes and with wide area transponder coverage. Examples of Phase III satellites are the ill-fated Phase IIIA, OSCAR 10, and the soon to be launched Phase IIIC. Phase IV satellites are now in the study and design phase and crown this development cycle with geosynchronous "constant" position orbits providing 24 hour/day communications over nearly half the globe per satellite.

OSCAR IV was ahead of its time by 2.5 decades with a Phase IV mission, that we now plan for the early 1990s.

OSCAR Satellite Characteristics

As would be expected in a progression of satellite designs covering 2.5 decades, substantial advancements have been made in the features and capabilities of the OSCARs. Correspondingly, satellite mass, cost and complexity have increased. OSCARs I and II were literally