TOMS-M-1005

PROJECT DESCRIPTION
FOR
METEOR-3/TOMS

(TOTAL OZONE MAPPING SPECTROMETER)

FEBRUARY 1992

GODDARD SPACE FLIGHT CENTER

FORWARD

This document provides Goddard Space Flight Center's (GSFC) Project Description for the Meteor-3/TOMS mission. The Meteor-3/TOMS mission is a joint USA/USSR scientific program in which a US Total Ozone Mapping Spectrometer (TOMS) instrument will fly on a USSR Meteor-3 spacecraft. The National Aeronautics and Space Administration (NASA) has initiated the Meteor-3/TOMS Project to provide a continuation of the decade-long global coverage obtained with the Nimbus-7 TOMS instrument. The scientific goal is to gather global total ozone data of an environmental importance to both countries as well as to all peoples of the earth.

This document was developed by personnel from NASA/GSFC's Laboratory For Atmospheres (Code 910) and the Aerospace Engineering Group of International Development and Energy Associates, Inc (IDEA). This effort was in response to a work request from Code 910 of NASA/GSFC to IDEA under Task 011 of contract NAS5-31729. The GSFC technical monitor on this task was Mr. Charles Cote and the IDEA task leader was Mr. Charles Perrygo.

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ACRONYMS & ABBREVIATIONS

BCU	Bench Checkout Unit
BUV	Backscatter Ultraviolet
cm	centimeter
ELM	Electronics Module
FM	flight model
FOV	field-of-view
FVNIIEM	Subsidiary of All-Union Research Institute for Electromechanics
FY	fiscal year
g	gravity (unit of acceleration)
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HD	high density
hr	hour
Hydromet	USSR State Committee for Hydrometeorology
Hz	Hertz (cycles per second)
IAM	Instrument Adapter Module
IFOV	instantaneous field-of-view
kg	kilogram
MFR	Memorandum for Record
mm	millimeter
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NIST	National Institute for Standards and Technology
nm	nanometer
NSSDC	National Space Science Data Center
OPM	Optics Module
PMT	photomultiplier tube
QBO	quasi-biennial oscillation
RF	radio frequency
sec	second
TOMS	Total Ozone Mapping Spectrometer
US	United States
USSR	Union of Soviet Socialist Republics
UV	ultraviolet
VFC	voltage-to-frequency counter
VNIIEM	All-Union Research Institute for Electromechanics
W	Watt

1.0 MISSION DESCRIPTION

1.1 IDENTIFICATION

Meteor-3/TOMS is the project title designated by the Office of Space Science and Applications. It is designed to provide for the development, integration, and operation of a Total Ozone Mapping Spectrometer (TOMS) instrument on a USSR Meteor-3 spacecraft. The Unique Project Number (UPN) assigned is 618-42. A FY 1989 new start was approved.

1.2 MISSION SUMMARY

This mission will provide a continuation of the 12-year global coverage obtained with the Total Ozone Mapping Spectrometer (TOMS) instrument on the Nimbus-7 spacecraft and permit assessment of climate time-scale changes in the spatial distribution of total ozone and volcanic sulfur dioxide. The behavior of ozone is of major interest because of potential climatic and biological effects of reduced ozone levels. The schedule for present and future TOMS missions is shown in Figure 1-1.

In April 1987, then Secretary of State Shultz and Foreign Minister Shevardnadze signed the *US-USSR Agreement Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes*. This agreement basically stated that the two countries should work jointly on outer space projects. In May 1988, during the Moscow Summit, this agreement was formally expanded by Presidents Reagan and Gorbachev to permit the exchange of science instruments for flight on the other country's spacecrafts. This historic event paved the way for the Meteor-3/TOMS program to take place, the first such program approved under the expanded agreement. In July 1990, NASA Headquarters and the USSR State Committee for Hydrometeorology (Hydromet) signed the *Meteor-3/TOMS Implementing Agreement*, delineating the activities and responsibilities of NASA and Hydromet for the Meteor-3/TOMS mission.

The Meteor-3/TOMS mission is a joint USA/USSR scientific program in which a US Total Ozone Mapping Spectrometer (TOMS) instrument, including associated interface and data storage equipment, are integrated on a USSR Meteor-3 spacecraft. Meteor-3/TOMS will be launched into a polar orbit on a USSR Cyclone launch vehicle for a two year mission. The TOMS instrument is designed to produce a global map of the spatial distribution of total ozone on a daily basis. The goals and objectives of this mission are briefly described below.

Scientific goal:	Gather global total ozone data of an environmental importance to both countries as well as to all peoples of the earth
Technological goal:	Improve the quality of satellite measurements of ozone through comparison of coincident data
Programmatic objectives:	Establish avenues of communication between the countries at both scientific and technical levels to help resolve the question of global ozone modification

As set forth in the Implementing Agreement, NASA will provide flight and ground support equipment, documentation, and services. Hydromet will provide facilities, flight hardware, documentation, launch services, mission operations, and pertinent spacecraft and TOMS housekeeping data. NASA personnel will verify post-delivery performance, track pre-launch performance, assist integration of the flight unit on the spacecraft, and track post-launch performance. Hydromet will be responsible for partial monitoring of TOMS health and safety, and for uplinking commands in a timely fashion.

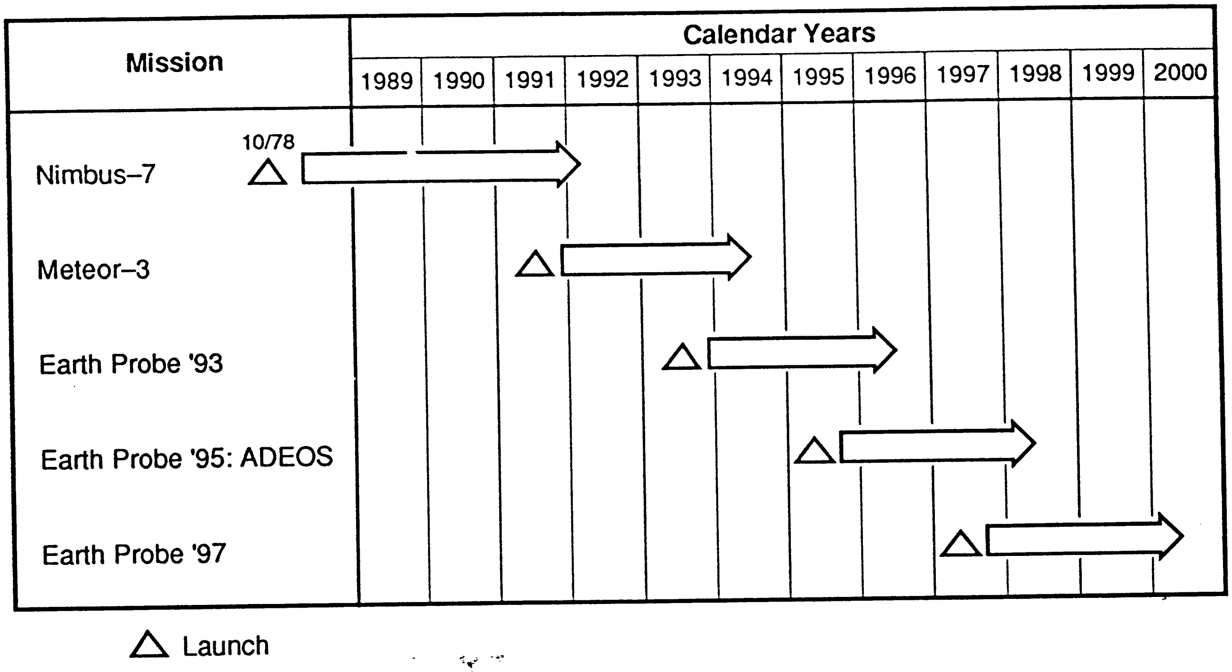


Figure 1-1. TOMS Missions for Ozone Trend Investigations

Hydromet mission operations include monitoring the health of TOMS, transmission of TOMS command sequences, and commanding playbacks of recorded data over appropriate ground stations. NASA will familiarize and train a limited number of Hydromet scientific staff on the performance, evaluation, and space borne operations of TOMS that are necessary for Hydromet to conduct their TOMS support.

Data collection includes receipt of the data by ground stations and transmission of the data to processing centers in the US and USSR. Data exchanges may be necessary between NASA and Hydromet in case of technical difficulties. NASA and Hydromet will work jointly to define and establish requirements for the implementation of data transmission links for preflight and postflight communications. The two sides will continue collaboration and collection of data for the life of the mission. NASA and Hydromet will form a Science Working Group to coordinate these activities and to produce a validation plan. This working group will meet at least semiannually.

1.3 SCIENCE BACKGROUND

Ozone is a natural photochemical constituent of the stratosphere. Because of its absorption properties in the ultraviolet (UV) region of the spectrum, ozone is one of the most important molecules in the atmosphere. Ozone, which comprises less than one part per million of our total atmosphere, absorbs virtually all of the solar radiation incident on the Earth between the wavelengths of 200 and 300 nm. The small amount of UV radiation which penetrates to the surface has been connected with deleterious effects such as sunburn and skin cancer.

Research over the past few decades has shown that the amount of ozone in the atmosphere may be affected by a number of factors. Among these are: the increasing abundances of man-made trace gases such as chlorofluorocarbons (CFCs); variations induced by the 11-year solar cycle; volcanic eruptions; and natural internal oscillations in the atmospheric dynamic system such as the quasi-biennial oscillation (QBO) or the El-Niño Southern Oscillation. Global decreases in ozone have been predicted due to the growth of CFCs in the atmosphere. Measurements from the Nimbus-7

TOMS have detected a global 2.6% ozone decrease over the past decade Decreases in ozone produce increases in biologically active UV radiation at the earth's surface, and can cause changes in atmospheric circulation from decreased heating of the upper atmosphere.

The TOMS instrument has revealed the detailed nature of total ozone variations in a 12-year global record obtained during the Nimbus-7 mission. The data have revealed a complexity in the variations of total ozone that varies from day to day and year to year. For example, the Antarctic ozone hole has changed in its depth in an interannual progression in a way that is not simply related to the growth of CFCs in the atmosphere. Correlation with the quasi-biennial oscillation and solar cycle modulations have been found. However, confirmation requires a data record longer than one solar cycle. All of the sources of modulation of total ozone need to be understood before the ultimate environmental effects of air pollution can be predicted with confidence. This requires a continuous record of global total ozone observations for several decades.

TOMS is designed to map the spatial distribution of total ozone by measuring the atmospheric albedo of the sunlit earth at six selected wavelengths in the ultraviolet region of the spectrum. The field-of-view of the instrument is swept across the spacecraft ground track to produce a swath of observations which bridges the region between adjacent orbits to produce spatially contiguous global coverage. The Meteor-3 TOMS will provide a high resolution map of the global total ozone on a daily basis.

1.4 MISSION SCIENCE OBJECTIVES

1.4.1 Primary Science Objectives

The primary science objective is to continue the observation of environmentally important ozone changes. The scientific priorities for this mission are as follows.

(1) Continue the precise global total ozone climate data base of Nimbus-7 TOMS in order to monitor the change due to man's activities and natural changes.

(2) Maximize possible coverage of the ozone at Antarctic latitudes during months of September and October to provide continued coverage of the Antarctic ozone hole.

(3) Maximize possible coverage of the ozone at Arctic latitudes during the month of February, augmented with coverage during January and March to determine whether related ozone depletions occur in the Arctic.

1.4.2 Secondary Science Objectives

(1) Diagnose lower stratospheric dynamical phenomena. Studies performed on the Nimbus-7 TOMS data have shown that strong spatial gradients in the ozone data are associated with strong gradients in the tropopause height. Thus, one can clearly delineate the jet streams on TOMS ozone maps. Relationships have also been drawn between these strong gradients and the genesis of severe storms.

(2) Track and analyze of sulfur dioxide clouds from volcanic events. Sulfur dioxide has strong absorption features in the ultraviolet that can compete with ozone. The absorption is typically negligible, except locally during a volcanic eruption. Nimbus-7 TOMS has seen numerous volcanic eruptions and followed each sulfur dioxide cloud for one or more days. The total amount of sulfur dioxide can be estimated and has been used to estimate the output of magma.

Additionally, the US Shuttle program has requested information on sulfur dioxide clouds during Shuttle landings. Sulfur dioxide is known to cause pits on Shuttle windows when the Shuttle passes through sulfur dioxide clouds during entry.

(3) Provide coverage of ozone during related field experiments, focusing on both ozone depletion and meteorological research, that may be conducted by Hydromet and NASA.

(4) Take advantage of the Meteor spacecraft's orbital drift to improve the ability to accurately obtain ozone data at high solar zenith angles. This can be accomplished by combining the Meteor-3 TOMS high solar zenith angle equatorial ozone data with Nimbus-7 TOMS data. The resulting algorithm improvement will improve our understanding of polar ozone changes

1.5 MISSION SUCCESS CRITERIA

A successful mission will be one that accomplishes the primary science objectives stated in Section 1.4. This requires success in the following stages.

(1) Achieve planned orbit
(2) Successful TOMS instrument turn-on
(3) Successful calibration sequences
(4) Successful ground reception of TOMS instrument data
(5) Production of Daily Global Ozone Data Sets
(6) Successful correlation with Nimbus-7 TOMS ozone data sets

1.6 MISSION PROFILE

NASA and Hydromet will work together to identify the optimum time for launch of the Meteor-3/ TOMS mission considering the scientific priority of the mission. The currently expected launch date is August 15, 1991. The NASA team will be present at the launch of Meteor-3. After launch, activation of Meteor-3 will be controlled by Hydromet. The NASA team will be kept informed of the progress and participate in the activation of the TOMS instrument. TOMS will be allowed to outgas for a nominal seven day period before being fully activated.

Normal operating command sequences will be prepared by NASA and sent to Hydromet, and will cover a period of 14 days. Hydromet will provide NASA the spacecraft orbit elements in sufficient time for NASA to produce the command sequences for the next period. Solar calibration times will be calculated by NASA and the appropriate commands included in the command sequences. Real time commands will be sent to TOMS for initial turn on, special operations, and emergencies. Hydromet is responsible for transmission of commands to the Meteor-3 spacecraft.

TOMS science data will be recorded for 13 orbits (= 1 day) and then downlinked to the USSR and US ground stations. Normal operations will sample all TOMS housekeeping data one orbit every two weeks.

TOMS will be left on unless emergency conditions require turn-off. The NASA Mission Operations Manager will be notified at once of any power interruptions or any other Meteor-3 actions that affect TOMS.

2.0 DATA PRODUCTS

A quarterly status report will be produced, showing the instrument condition, preliminary ozone, and correlative measurements from other data sources. In addition, a data atlas will be prepared.

2.1 DATA COLLECTION

The TOMS data will be downlinked separately twice each day in the USSR and twice each day in the US. The same recorded data is transmitted during every downlink each day. The second downlink is to assure good data transmission and will not be kept if the first transmission is acceptable. The US receiving station will be at the Wallops Orbital Tracking Station located at the GSFC/Wallops Flight Facility, and the main USSR receiving station will be at Obninsk.

In the event that either the NASA or Hydromet ground station misses a pass of the spacecraft, the parties agree to exchange recorded raw scientific ozone data for the time period missed. NASA and Hydromet will work jointly to define and establish requirements for the implementation of data transmission links for preflight and postflight communications.

2.2 DATA PROCESSING

The existing algorithm for TOMS total ozone retrievals was developed in 1978 for the launch of Nimbus-7. This algorithm is an adaptation of the algorithm developed for the Nimbus-4 Back-scatter Ultraviolet (BUV) Spectrometer. The TOMS algorithm was significantly enhanced in 1990 to make possible the high accuracy needed for determining ozone trends. Minor modifications were made in 1983 to account for sulfur dioxide contamination during volcanic eruptions and again in 1986 to account for changes in ozone absorption coefficients after measurements at National Institute of Standards and Technology.

Following launch, both NASA and Hydromet will receive and process the TOMS flight data. NASA will process the raw flight data through the TOMS algorithm to produce total ozone data in the current Nimbus-7 TOMS format. Hydromet will provide general spacecraft parameters for use in data reduction algorithms. Hydromet will also provide precise time, location, and periodic spacecraft attitude information. This information along with TOMS service telemetry will be delivered by Hydromet to the NASA data processing center as an individual set of data through organizations under Hydromet.

NASA will produce instrument calibration data sets from ground testing for use in production of data sets for archival by the Soviet Central Aerological Observatory. These will consist of instrument wavelength determinations, calculation of effective ozone absorption coefficients, albedo-ozone gradients for the wavelength pairs, and radiance-irradiance parameters for the TOMS instrument. These data sets will be provided before launch of the Meteor-3/TOMS. Hydromet will perform an independent reduction of all telemetry data using an overall algorithm developed at Hydromet.

The total ozone computed from these algorithms will be compared with each other and with other data sources such as Dobson, Lidar, ozonesondes, and with other available scientific data from US and Soviet spacecraft and ground stations.

2.2.1 Data Levels

The data levels for the Meteor-3/TOMS mission are described below.

Level 0 TOMS data converted to counts in major frame format

The TOMS instrument data is converted from raw telemetry to counts in major frame format. Initial data quality checks are performed with flags set to indicate problems.

Level 1 Raw counts, scan angle, zenith angle, day number, etc.

The TOMS data are converted from major frames into a form suitable for scientific data analysis. The spacecraft clock, which is included in the TOMS data, is corrected and smoothed to produce an accurate time for each major and minor frame. Raw count ozone data are associated with the location of the viewed scene on the earth, instrument scan angle, the solar zenith angle, day number, and orbit number. Engineering data checks and additional quality checks are also performed.

Level 2 Analyzed ozone data versus latitude, longitude, day number, etc.

Raw counts are combined with instrument calibration data to produce radiance and irradiances for each wavelength channel at the previously determined earth location. Radiance-irradiance ratios (directional albedos) from each channel are combined into wavelength pair ratios (N_p-values) to minimize calibration uncertainties. The long wavelength channels, 360 and 380 nm, are used to determine the lower boundary reflectivity and cloud height for each scene. Using precomputed tables based on a climatological ozone data base, the N_p-values are converted into ozone amounts. Additional data quality checks are performed on the physical quantities (e.g., reflectivity, ozone, etc.) to insure proper inversion of the radiances into ozone values.

Level 3 Analyzed ozone data: maps, grids, plots, etc.

The analyzed data produced in Level 2 processing is combined into an approximately 1° X 1.25° grid covering the sunlit portion of the globe for each day. Overlapping data are appropriately weighted for inclusion within each grid cell. The results are provided in both numerical and graphical formats. The graphical format is a color contour plot with a 50-Dobson unit ozone resolution. It is expected that this product will be the most widely distributed form for use by the scientific community and general public.

2.2.2 Data Handling Responsibilities

Data handling responsibilities between NASA and Hydromet are divided as follows:

Hydromet:

- Spacecraft operations
- Production of Level 0/1/2/3 data products for use by Hydromet
- Uplinking of TOMS command messages
- TOMS housekeeping data monitoring
- TOMS telemetry monitoring
- Periodic spacecraft attitude telemetry sampling
- Spacecraft orbit element determination

NASA:

- Generation of TOMS command sequences
- Production of of Level 0/1/2/3 data products for use by NASA
- TOMS instrument status monitoring
- Declaration of emergencies
- Generation of TOMS calibration data sets which will be transmitted to Hydromet

Joint NASA/Hydromet:

- Operational communications
- Scientific analysis of TOMS data

2.3 DATA EXCHANGE & DISTRIBUTION

Representatives of NASA and Hydromet will meet periodically to review the status of the instrument and the ozone data. An initial joint publication will be produced in an agreed upon journal. The initial publication will describe the instrument and its calibration, and provide a sample of the ozone data obtained by Meteor-3/TOMS. Subsequent publications may be prepared jointly or separately.

Following launch, the solar calibration data will be analyzed independently by NASA and Hydromet analysis groups to determine changes in the diffuser plate reflectance with time as required to produce measurements of the trends of global ozone. Any differences will be reconciled by the two groups to produce the best calibration. The accuracy of reflectivity determinations increases with length of data record so that several improved calibrations will be provided during the life of the Meteor-3/TOMS flight.

NASA and Hydromet will each be entitled to receive all raw flight data from TOMS and may reproduce, use and disclose for any purpose at their discretion. It is the intention of both NASA and Hydromet that the raw, processed, and analyzed data will be made available to the international scientific community through publication or other appropriate means.

2.4 DATA ARCHIVING

Both NASA and Hydromet will deliver TOMS Level 2 and Level 3 archival ozone data tapes to the National Space Science Data Center (NSSDC).

3.0 KEY PROJECT SUPPORT PERSONNEL

3.1 US PERSONNEL

Charles E. Cote	Project Manager	Laboratory for Atmospheres, Code 910 NASA/Goddard Space Flight Center
Dr. Robert Hudson	Initial Project Scientist	Atmospheric Chemistry and Dynamics Branch, Code 916 NASA/Goddard Space Flight Center
Dr. Arlin J. Krueger	Instrument Scientist	Atmospheric Chemistry and Dynamics Branch, Code 916 NASA/Goddard Space Flight Center
Dr. Jay R. Herman	Project Scientist for Data	Atmospheric Chemistry and Dynamics Branch, Code 916 NASA/Goddard Space Flight Center
John J. Loiacono	Instrument Manager/ Project Engineer	Atmospheric Experiment Branch, Code 915 NASA/Goddard Space Flight Center
Michael L. Forman	Instrument Operations Manager	Project Operations Branch, Code 513 NASA/Goddard Space Flight Center
Holland T. Bell	Head, Data Acquisition	Data Acquisition Branch, Code 833 NASA/Goddard Space Flight Center
Stanley H. Way	Deputy Project Manager	Atmospheric Experiment Branch, Code 915 NASA/Goddard Space Flight Center
Arnold G. Oakes	Data Processing Manager	Information Systems Development Facility, Code 936 NASA/Goddard Space Flight Center
Eve M. Abrams	Contamination Engineer	Thermal Engineering Branch, Code 732 NASA/Goddard Space Flight Center

3.2 USSR PERSONNEL

N. Petrov	Deputy Head of Main Department of the USSR State Committee for Hydrometerology (Hydromet)
V. Adasko	Director of All-Union Research Institute for Electromechanics (VNIIEM)
V. Khattatov	Deputy Head, Central Aerological Observatory
B. Morozov	Head of Space Systems Agency, Ministry of Defense
S. Konyukhov	General Designer of "YUZHNOYE" Design Bureau
O. Federov	Responsible Member of the USSR Council of Ministers
K. Makarov	Head of FVNIIEM subsidiary of All-Union Research Institute for Electromechanics
Yu. Trifonov	Deputy Director of All-Union Research Institute for Electromechanics (VNIIEM)
Yu. Kazakov	Deputy Head, International Department of USSR GOSHYDROMET
R. Salikhov	Deputy Head, FVNIIEN
A. Volkov	Deputy Head, "Planeta" Scientific Industrial Association
V. Mistshyuk	Deputy Director of TV Scientific Research Institute
V. Mekscha	Head of Space Systems Division, Ministry of Defense
G. Petrenko	Head of Department, FVNIIEM
A. Vladimirov	Head of Department, FVNIIEM
A. Korotkov	Head of Department, FVNIIEM
G. Tolmachev	Head of Laboratory, FVNIIEM
A. Danilov	Interpreter, Central Aerological Observatory

4.0 SPACE SEGMENT

The space segment consists of the TOMS Instrument Assembly, the Interface Adapter Module (IAM), and the Meteor-3 spacecraft. NASA will provide the TOMS Instrument Assembly and IAM. USSR flight hardware to be provided is the Meteor-3 spacecraft, the Cyclone launch vehicle, and all on-board facilities required to operate the TOMS and IAM, such as power, timing, and commanding of instrument modes by stored and real time commands.

4.1 TOMS INSTRUMENT DESCRIPTION

The TOMS is a spectrometer using a single Elbert-Fastie monochromator with a fixed grating and an array of exit slits. Functionally, the TOMS measures the radiance backscattered by the atmosphere in six spectral bands during the daylight portion of the orbit. Once per day, as the spacecraft crosses over the day-to-night terminator, a diffuser plate is viewed by the instrument for solar calibration. The instrument views sunlight reflected off of the diffuser plate to obtain a solar irradiance measurement for reference. The stability and characterization of the diffuser plate is therefore a major aspect of system calibration.

The TOMS has a 3° X 3° instantaneous field-of-view and measures six discrete wavelengths ranging from 312.5 to 380 nm with a 1 nm bandwidth. The TOMS uses a cross-track scanner to map the global ozone distribution as the spacecraft orbits the earth. The scanning mirror scans ±51° from nadir in three-degree steps, producing a total of 35 scenes per scan. The scanner stops at each scene while an optical chopper sequentially gates the wavelengths to the detector for processing.

In addition to various housekeeping sensors for monitoring the well-being of the system, the TOMS is also provided with in-flight wavelength calibration and electronic calibration modes for periodic assessment of the radiometric system performance. These in-flight calibration modes are designed to check the stability of the monochromator wavelengths in radiance and irradiance modes and the gain stability of the signal processing electronics.

The design operating lifetime for TOMS is two years.

4.1.1 Instrument Heritage

TOMS is a second-generation ozone sounding instrument, derived from the Nimbus-4 Backscatter Ultraviolet (BUV) ozone sounding spectrometer, which was launched in 1970. It was the large spatial variability of total ozone observed with the BUV that led to the proposal to build the TOMS instrument for the Nimbus-7 spacecraft. Compared to the BUV, the TOMS instrument provides more precise results and total ozone field mapping as opposed to just vertical profiles of ozone. The Nimbus-7 spacecraft was launched in October 1978 and the Nimbus-7 TOMS has operated continuously since that time.

For the Meteor-3/TOMS mission, the Nimbus TOMS Flight Model 1 (FM-1) engineering model will be refurbished to flight status, becoming FM-2 in the process. Improvements and changes incorporated into FM-2 are:

- Bake-out of all materials that mechanically support optical elements
- Mounting of the Optics Module and Electronics Module to the same base plate
- New base plate structure
- Replacement of electronics components

- Replacement of most optical components
- Addition of three-plate Diffuser Module

To provide a simplified interface between the TOMS and the Meteor-3 spacecraft, an Interface Adapter Module (IAM) will be added. Both engineering and flight model IAMs will be fabricated.

4.1.2 Hardware Description

The TOMS instrument, illustrated in Figure 4-1, includes the following assemblies:

- TOMS FM-2 Instrument Assembly
- Interface Adapter Module (IAM)
- Interconnecting flight cables

The FM-2 Instrument Assembly includes the Optics Module (OPM), Electronic Logic Module (ELM), Diffuser Module, and base plate. The IAM consists of the interface electronics, data recorder, and base plate. The Instrument Assembly and IAM each has a mass of 28 kg.

4.1.2.1 TOMS Optical System

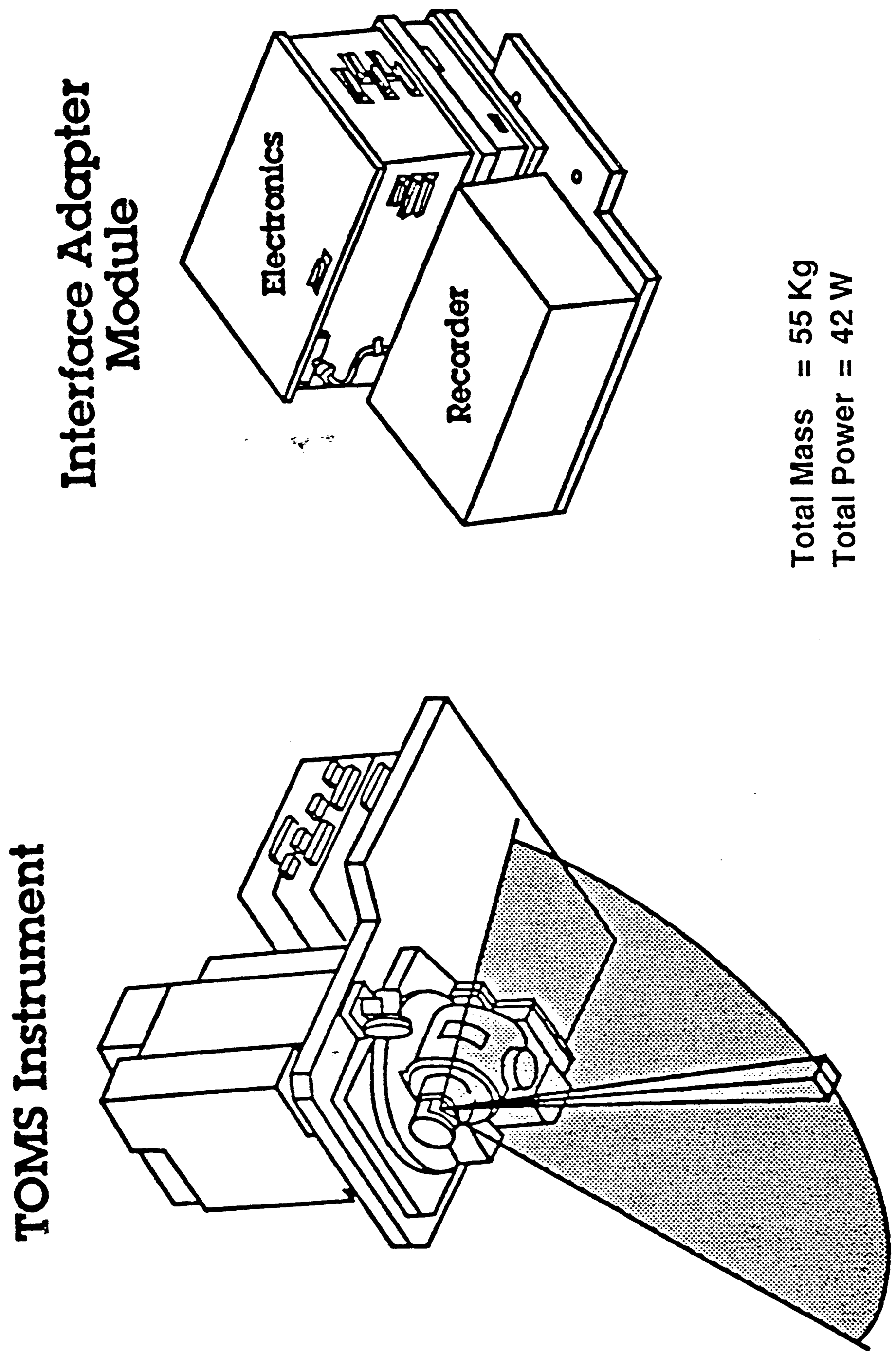
The TOMS optical system is shown schematically in Figure 4-2. The major TOMS optical subsystems are:

- Diffuser Module
- Cross-Track Scanner
- Depolarizer
- Objective Lens
- Slit Assembly and Chopper/Wavelength Selector
- Monochromator Optics
- Exit Lens
- Photomultiplier Tube
- Mercury Calibration Lamp

The above items, with the exception of the Diffuser Module, comprise the Optics Module. These items are briefly described below.

Diffuser Module: The TOMS measure solar irradiance and earth radiance. A diffuser plate is used to convert the incident solar flux into diffuse radiation. Since the ozone measurement is based on the radiance to irradiance ratio, the reflectance of the diffuser plate must be known accurately. However, the spacecraft environment causes a slow degradation of the diffuser plate reflectivity which is wavelength, exposure, and time dependent. Because the amount of reflectivity degradation cannot be accurately predicted, the TOMS FM-2 will utilize a carousel assembly containing *cover*, *working*, and *reference* diffuser plates. Use of these diffuser plates is discussed in Section 4.1.3.2. The diffuser plates consist of a ground aluminum plate overcoated with vacuum-deposited aluminum and magnesium-fluoride. A stepper motor drive can advance the carousel both forward and backward to expose the desired reference plate. The assembly is heated and normally kept in the cover-plate-exposed position to provide contamination protection.

Because the Nimbus-7 TOMS utilized the single diffuser plate of the Solar Backscatter Ultraviolet (SBUV) instrument, the Diffuser Module is a new hardware item for the Meteor-3 TOMS.



Total Mass = 55 Kg
Total Power = 42 W

Figure 4–1. TOMS Flight Hardware

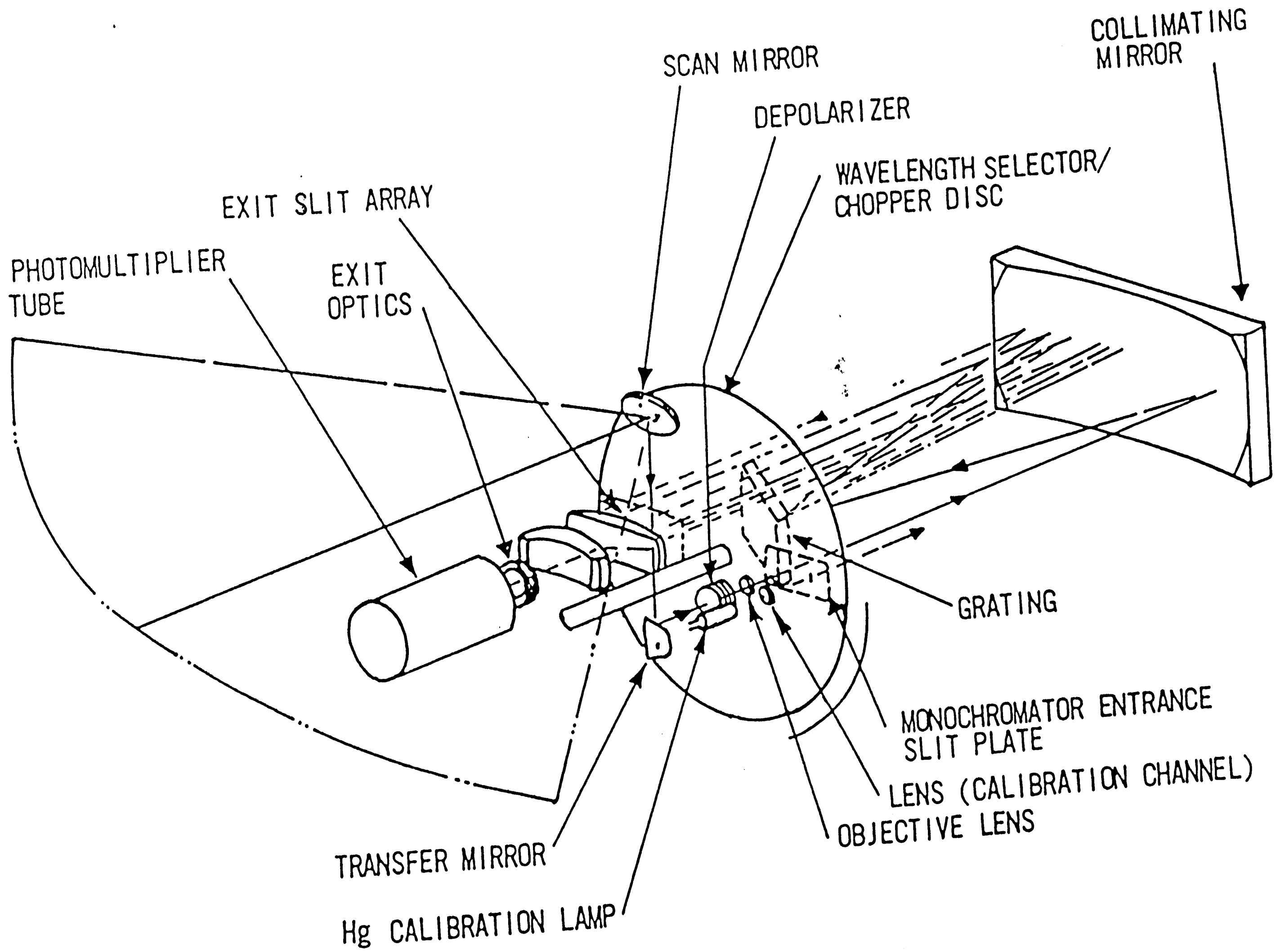


Figure 4–2. TOMS Optical System

Cross-Track Scanner: The cross-track scanner is a 45° angle fold mirror mounted on a three-degree-step-size stepper motor. An encoder measures the position of the mirror. In earth scan operation, the scanner views each scene in sequence from one side of the flight track to the other and then retraces to start the next scan. Other special positions are for viewing the diffuser plate and for stowing the scanner for protection during shipment, launch, and orbital maneuvers.

The scanner is positioned through 35 scene positions in a scan, yielding a scanned field-of-view of 105°±0.1°. The total time spent at each scene is 200 ms, which includes 168 ms for data sampling and 32 ms for scanner repositioning and settling. The time thus required to scan all 35 scene positions is seven seconds. With one second allowed for retrace time, a total of eight seconds per scan is required.

Depolarizer: The TOMS monochromator responds differently to light of varying polarization. Since the backscattered radiation from the atmosphere contains a polarized component, a depolarizer is required to minimize this effect. The TOMS depolarizer is made of two retarders cut from optical grade calcite (Lyot design). The residual polarization sensitivity is less than 5%.

Objective Lense: The TOMS objective lens is made of fused silica with a nominal focal length of 13 mm. The instantaneous field-of-view (IFOV) is imaged on the entrance slit after passing through the chopper. The full-width half-maximum IFOV of TOMS is nominally 3°±0.1° square at each scanner step, with some instrument response extending out to 4° square. Based on a 3° X 3° IFOV, the spatial resolution at a 1202 km orbit altitude is:

Nadir Viewing Direction:	64 X 64 km
Average Viewing Angle:	85 X 85 km

Slit Assembly and Chopper/Wavelength Selector Assembly: The TOMS has one entrance slit and six exit slits in the main optical system. There is also a separate aperture for introducing radiation from a mercury calibration lamp to perform in-flight wavelength calibration. Wavelength selection is performed by precisely locating apertures in the chopper wheel. Thus a single mechanism performs both optical chopping and wavelength selection, minimizing the number of mechanisms and improving the wavelength precision. Output wavelengths are verified during final assembly.

Monochromator Optics: The monochromator optics consist of a grating and an Ebert mirror. The Ebert mirror both collimates light from the entrance slit onto the grating and also focuses light from the grating onto the exit slit. With an Ebert mirror focal length of 250 mm and a grating size of 52 X 52 mm, the TOMS monochromator is f/5. The grating is holographically blazed with 2400 groves/mm, producing a linear dispersion of 1.3 nm/mm.

Both the grating and the Ebert mirrors use low scintillation fused silica substrates with enhanced UV coatings and a low scatter polish. Both elements are front mounted against lapped surfaces to maintain optical alignment through launch vibration. This technique is highly successful in maintaining optical alignment as proven on several Nimbus instruments.

Exit Lenses: The exit lenses form an image of the grating on the photomultiplier tube (PMT). The six different wavelengths are thus measured using a common detector. All three components of each lens are made from low-scintillation fused silica to minimize radiation induced fluorescence in the volume of the lens material.

Photomultiplier: The TOMS radiation detector is a Bi-alkali photomultiplier utilizing a faceplate made from selected low-scintillation fused silica. The photon flux is sufficiently high in the TOMS so that a relatively low gain PMT suffices. The TOMS PMT is shielded against particle radiation and magnetic flux to minimize induced noise.

Mercury Calibration Lamp: A mercury calibration lamp illuminates a mercury calibration slit in the chopper/wavelength selector wheel to perform wavelength calibration.

4.1.2.2 Electronic Logic Module (ELM)

The signal processing electronics in the ELM are identical to the Nimbus-7 TOMS. In data recording, the chopped optical signal from the exit slit generates a current in the photomultiplier tube (PMT). This current drives four electrometer amplifiers in parallel. Each amplifier employs a different gain to span the input energy range. A summing node at each electrometer input accepts ether the PMT output (during normal data acquisition modes) or a precise signal pulse (during Electronic Calibration Mode). Each electrometer drives a dedicated voltage-to-frequency counter (VFC) that performs analog-to-digital conversion on each of the four parallel gain stages. The four VFCs output to four accumulators which are controlled and synchronized to the optical chopper. The accumulators count up when light is admitted to the PMT and count down when the chopper blocks light to the PMT. In this manner, the the resultant value represents the actual input signal minus the dark current and other currents not synchronous with the chopper. The accumulator thus operates as an integrator and synchronous demodulator, rejecting any DC components in the signal.

Other functions provided by the ELM are briefly described below.

Analog Housekeeping Data: An analog multiplier multiplexes the outputs from the various voltage, current, and temperature sensors into a dedicated housekeeping VFC.

Calibration Lamp Control: The wavelength calibration lamp is driven by a dedicated analog regulator.

Chopper Servo Control: The precise speed and position of the TOMS optical chopper is controlled by a phase-locked loop containing an inner velocity loop and an outer phase loop. The chopper disc contains a one count per revolution encoder and a 2000 count per revolution encoder. The outer (phase) loop controls the angular position of the encoder so that the once per revolution encoder pulse is generated coincident with a reference 5 Hz clock frequency. The inner (velocity) loop controls the velocity of the chopper such that the 2000 count per revolution encoder generates pulses that match a reference 10 KHz clock frequency.

4.1.2.3 Interface Adapter Module (IAM)

The IAM effectively integrates the TOMS instrument as part of the Meteor-3 spacecraft and is designed for compatibility while imposing no adverse effects on either system. The IAM contains the electronics to interface TOMS to Meteor-3, the DC/DC converter, and the data recorder. The IAM converts the Meteor-3 power, commands, clock, telemetry, and data interfaces into a compatible system for TOMS. Power is provided to the TOMS, diffuser module, data recorder, and the IAM's own circuits. TOMS total power consumption ranges 17 to 39 Watts. The IAM satisfies the Meteor-3 requirements for a single-block access to inputs, outputs, and autonomous testing without removing TOMS from the spacecraft.

4.1.2.4 Data Recorder

The data recorder is an on-board storage system that is provided as part of the IAM to record measurements at the instrument sample rate through useable portions of the orbit. The TOMS science data are only meaningful during daytime portions of the orbit. Measurements will be stored on-board for approximately 13 orbits. The same stored data will be transmitted daily to NASA and USSR receiving stations.

4.1.2.5 Base Plates

All the TOMS assemblies will be mounted on two base plates which are attached to the Meteor-3 spacecraft instrument platform in mutually agreed upon locations. The base plates are designed for thermal and mechanical compatibility with the instrument platform. The TOMS Instrument Assembly requires definite orientation of its axes in relation to the spacecraft axes and has a bolt pattern in its base plate that guarantees unequivocal installation of all assemblies into the seating places of the spacecraft. This alignment is critical to the mission science.

4.1.2.6 Interconnecting Flight Cables

The interconnecting flight cables includes cables, flight quality connectors, and connector labels. NASA has provided Hydromet with mating connectors for the IAM-to-spacecraft cables.

4.1.3 Calibration

TOMS calibration consists of both prelaunch and in-flight efforts. First, the radiometric response of TOMS is established using standard reference sources. Responses of the various in-flight calibration systems are characterized over the range of anticipated operating conditions. This is performed prior to launch. After the TOMS is in orbit, the instrument is evaluated and the various in-flight calibration systems are used to provide the correlation to ground calibration.

4.1.3.1 Prelaunch Calibration

The prelaunch radiometric calibration of TOMS is composed of three parts: radiance calibration, irradiance calibration, and system linearity calibration. The TOMS instrument measures the UV solar irradiance on top of the earth's atmosphere and the earth radiance due to direct solar illumination. The irradiance measuring mode of TOMS uses the additional diffuser plate element in the instrument's optical path. The objective of the prelaunch radiance and irradiance calibrations is the determination of the instrument response to a known source.

4.1.3.2 In-Flight Calibration

The ground calibration must be corrected to the TOMS operating environment after launch. This is accomplished by using the ground calibration as a base and correcting calibration constants using housekeeping data and in-flight calibration data. Housekeeping sensors monitor the various voltage, current, and temperature parameters which impact the TOMS performance. The in-flight calibrations—solar calibration, wavelength calibration, and electronic calibration—monitor system spectral and radiometric responses.

Solar Calibration: A solar calibration cycle measures solar irradiance for calculating earth albedos. The TOMS contains a motorized diffuser module with three diffuser plates. To perform a solar calibration, the TOMS scan mirror views sunlight reflected off of one of the diffuser plates. The normally exposed plate is called the *Cover Diffuser* and receives most of the contamination and degradation. The second plate is the *Working Diffuser*, and is exposed weekly for primary data on solar flux for ozone data reduction. The third plate is the *Reference Diffuser*, which is exposed only once every 15 weeks and tests the deterioration of the other plates.

The diffuser plate is viewed at times when the spacecraft is near the earth terminator and performing a day-to-night type terminator crossing. Proper orbital parameters for illumination of the diffuser plate will be obtained for 59 days of every 106 days in orbit.

Wavelength Calibration: In-flight wavelength calibration is used to detect sub-Angstrom wavelength shifts in the monochromator due to shock, vibration, or thermo-mechanical distortions. Wavelength shifts affect the ozone inversion algorithm. Calibration is accomplished using auxiliary slits in the chopper wheel to perform a pseudo-wavelength scan of the 296.7 nm mercury line from the mercury calibration lamp. The wavelength and electronic in-flight calibrations are performed on the night side of the orbit to minimize the effect of earth radiance on the calibration.

Electronic Calibration: The gain stability of the signal processing electronics is checked by injecting precise simulated chopped signals into the input of each electrometer amplifier. Data are accumulated as in radiance measurements. Eight different input levels are automatically sequenced to test the full range of the amplifiers.

4.1.4 Interface Characteristics

4.1.4.1 Field-of-View Requirements

TOMS is primarily an earth viewing instrument. TOMS will be attached to a platform mounted to the earth viewing side (-Z axis) of the Meteor-3 spacecraft. The required field-of-view is ±1.5° from nadir along the spacecraft track and ±52.5° cross-track. Also, the TOMS diffuser plate requires an unobstructed view of the sun during times of solar calibration. This clear field of view must extend at least 15° from the spacecraft-sun direction and allow for variations of sun angle from the nominal orbit.

4.1.4.2 Mechanical/Thermal Requirements

The TOMS is packaged as two separate units, the Instrument Assembly and the IAM. These units are located separate from each other on the spacecraft. Both units are thermally connected to the Meteor-3 interface with heat pipes. The interface is thermally controlled to 20°±10°C by the spacecraft.

Mechanical alignment of the TOMS Instrument Assembly relative to the Meteor-3 spacecraft earth limb sensor will be measured using optical reference cubes mounted on both devices. This differs from typical Meteor-3 alignment practice which relies solely on the dimensional tolerances of the mechanical interfaces to achieve the desired alignment accuracy.

4.1.4.3 Electrical Power Requirements

The Nimbus-7 TOMS instrument utilized the Nimbus 28 VDC spacecraft power bus for all power. High current devices utilized the power bus directly. Low voltage power supplies generated the required power for the various circuits. A similar approach is used for the Meteor-3 TOMS with DC/DC power converters added to accept the Meteor-3 primary power bus. The IAM and Instrument Assembly require 42 Watts maximum, 26 Watts average, and meet all Meteor-3 spacecraft requirements for induced voltage and current transients.

4.2 METEOR-3 SPACECRAFT

Figure 4-3 illustrates the Meteor-3 spacecraft and the locations of the TOMS Instrument Assembly and IAM.

4.2.1 Spacecraft Subsystems

4.2.1.1 Attitude Control Subsystem

The Meteor-3 spacecraft utilizes a three-axis stabilization system to provide a nadir-pointing/fixed-yaw attitude. Attitude is sensed using a combination of gyros and a horizon sensor. The Meteor-3 horizon sensor is unique from US earth sensors. It employs a single nadir pointing optical sensor, a single scan mirror rotating about the yaw axis, and eight fixed mirrors arranged such that the sensor is provided earth limb crossing views eight times per rotation of the scan mirror.

Attitude is controlled using momentum wheels, with hydrazine thrusters used for unloading residual spacecraft momentum on previous flights. However, the thrusters were removed and replaced with magnetic torquer bars for this mission because of concerns of potential contamination of the TOMS instrument.

The specified pointing knowledge for the Meteor-3 attitude control subsystem is ±0.5° (3-sigma). Previous Meteor-3 spacecraft nadir pointing performance appears to be significantly better than this

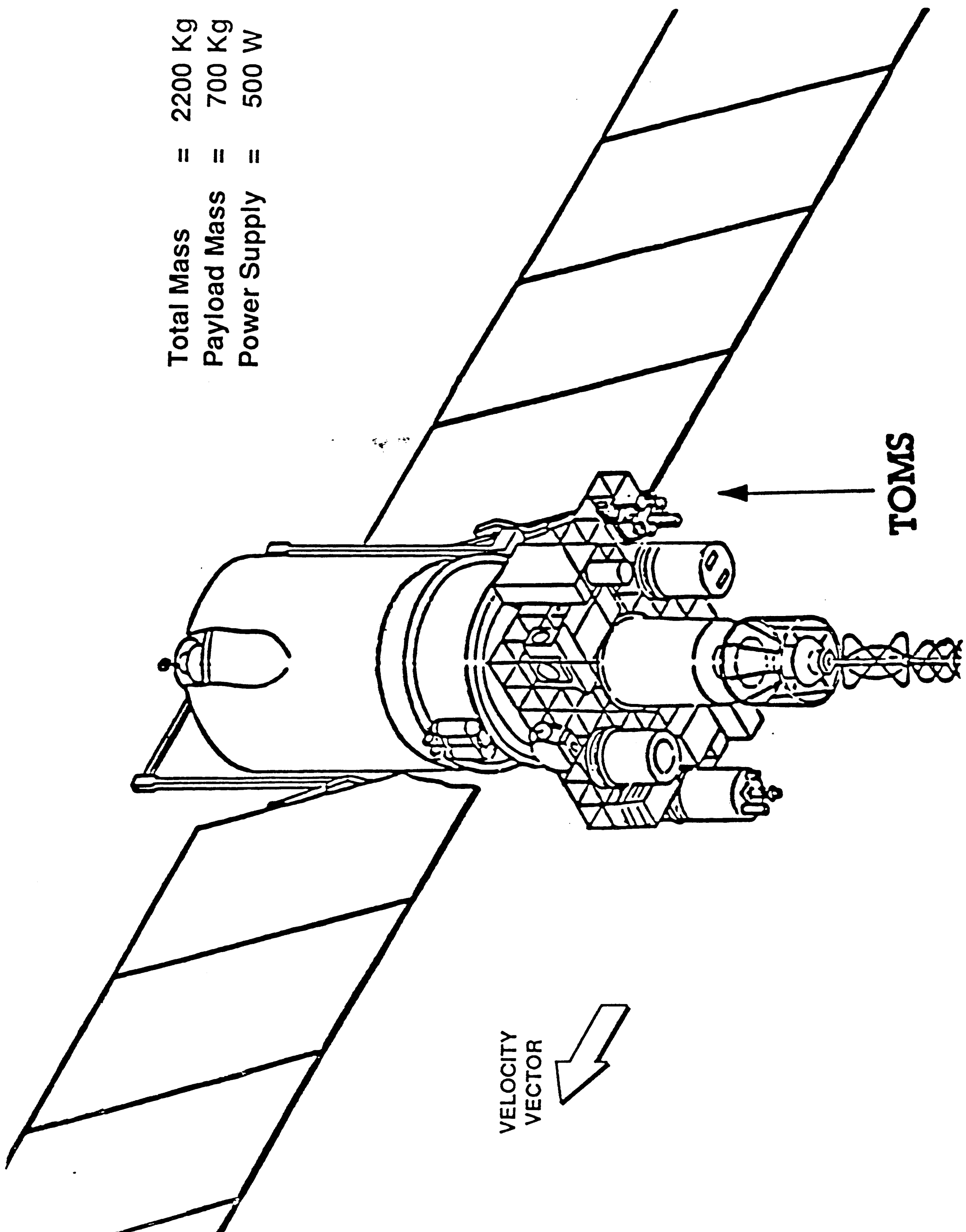


Figure 4–3. Meteor–3 spacecraft with the TOMS instrument

specified value, with nadir pointing control errors typically within a range of ±0.25° (3-sigma). Peak errors occur at day-to-night crossings when the spacecraft solar arrays are repositioned to the correct orientation for sunrise. Maximum error rates with respect to nadir are 0.01° per second.

4.2.1.2 Electrical Power Subsystem

Meteor-3 is powered by solar charged nickel-cadmium batteries. Primary power is provided at -24 to -34 volts unregulated, -27 volts nominal, and is not connected to the spacecraft chassis. Two independent battery modules are used for reliability—one set being charged while the other is driving the load. The power supply provides a total of 500 Watts, with power available at all times after launch except during emergencies.

4.2.1.3 Command & Telemetry Subsystem

Both programmed and real time command capabilities are available. Due to operational constraints, real time capability is normally used only for emergencies. Satellite uplink commanding will be controlled only by Hydromet. Nominal uplink commands are at 10 to 15 day intervals. Stored commands operate the satellite systems during these intervals.

Hydromet will record Meteor-3 service/telemetry channels which will contain TOMS housekeeping data. Complete TOMS housekeeping data will normally be recorded during one orbit every two weeks.

A 23 bit time code will be provided to TOMS. The code is formatted days (6 bits): hours (5 bits): minutes (6 bits): seconds (6 bits) of Moscow Standard Time. The Soviets will provide a time correction whose accuracy is 100 milliseconds. The IAM will generate sub-second time code for use by the TOMS.

4.2.2 Launch Vehicle

The Meteor-3/TOMS will be launched on a Soviet Cyclone launch vehicle from the Plesetsk Kosmodrome Complex, Plesetsk ,USSR. The location of Plesetsk within the USSR is shown in Figure 5-1.

4.3 MISSION ORBIT

Meteor-3/TOMS will be launched into a circular, non-sun synchronous, circumpolar orbit with the following nominal parameters.

Altitude:	1202 km
Inclination:	82.5°
Orbital period:	109 minutes
Orbit eccentricity:	< 1.11E-3
Orbit precession period:	212 days (relative to solar vector)

NASA and Hydromet will work together to identify the optimum date and time for launch of the Meteor-3/TOMS mission. This will require interactions between the scientific, spacecraft, orbit determination, and launch vehicle teams at NASA and Hydromet. The current estimate for date of launch is August 15, 1991. Optimum coverage of priority areas will be obtained with an ascending node near 1100 hours at the epoch of August 15, 1991.

4.4 CONTAMINATION CONTROL

The optical components of TOMS are sensitive to contamination by both particulates and hydrocarbons. Of particular concern is the diffuser module—a change in its reflectivity directly effects the accuracy of the ozone measurements. Although contamination by particulates is to be avoided, the major source of concern is contamination by hydrocarbons which can be polymerized by UV solar radiation.

To minimize contamination of the instrument during test and integration in the USSR, a set of procedures which specify the handling of TOMS will be defined in a Contamination Control Plan. This document will be provided by NASA before the first integration.

NASA personnel monitor contamination control procedures whenever the instrument is out of its shipping container to assure that the instrument is kept clean and to take appropriate action to remedy any areas of concern.

After launch, TOMS power will be turned on as soon as possible after injection into orbit to warm the instrument and diffuser plates. Maintaining the TOMS diffuser module at an elevated temperature reduces condensation of outgassing products on the diffuser plates.

4.5 GROUND SUPPORT EQUIPMENT

NASA provides Ground Support Equipment (GSE) adequate to perform the tests called for in the Integration and Test Plan. The GSE consists of a Bench Checkout Unit (BCU), assorted test cables, cable brake-out boxes, and hand-held meters. The BCU will include components to perform the functions of the Bench Test Equipment, Nimbus-7 spacecraft interface simulator, Meteor-3 spacecraft simulator, source illuminator, and external power supply. The BCU is able to test all functions of TOMS which are used in flight.

4.6 STORAGE & TRANSPORTATION

The TOMS Instrument Assembly and IAM will be delivered to Hydromet fully assembled. Special handling fixtures will be installed to provide support and a means of lifting without touching the Instrument Assembly or IAM. TOMS will be shipped to the USSR by air and within the Soviet Union by air or normal surface transportation. Special containers will be used for shipping and storage that will provide protection from contamination and excessive vibration and shock loads. The TOMS and IAM will be sealed in dry nitrogen-purged bags. Accelerometers mounted on the instrument handling fixtures will document the maximum shock load to which they have been exposed. The Instrument Assembly and IAM will not be exposed to temperatures outside the range of -10° to +45°C or shock greater than 6 g.

Hydromet will provide initial documentation and relevant paper work to the USSR Custom Office in order to minimize the USSR Customs clearance procedures and time required for the TOMS instrument to clear USSR customs. NASA personnel will accompany the TOMS Instrument Assembly and IAM through customs and during all transportation in the USSR. The TOMS Instrument Assembly and IAM will always be loaded, transported, handled, and unloaded under the supervision of a representative from NASA. The TOMS shipping containers will not be opened for any reason, including customs inspection, except in a clean room environment of Class 100,000 or better and while accompanied by NASA personnel.

5.0 GROUND SEGMENT

5.1 TRACKING & COMMUNICATION FACILITIES

The NASA satellite downlink telemetry system will be supported by the Wallops Orbital Tracking Station located at the GSFC/Wallops Flight Facility, Wallops Island, Virginia. An RF receiving system will be installed to support the 466.5 MHz downlink. The system proposed will not have autotrack capability—program tracking from a computer will be used instead. The main USSR receiving station is located approximately 100 km southwest of Moscow at Obninsk, as shown in Figure 5-1. Obninsk is located at 55.05° North latitude, 37.37° East longitude. Figure 5-2 illustrates the flow of telemetry and commands in the Meteor-3/TOMS mission.

5.2 MISSION OPERATIONS

5.2.1 Launch and Activation

The NASA team will be present at the launch of Meteor-3/TOMS. After launch, activation of Meteor-3 will be controlled by Hydromet. The NASA team will be kept informed of the progress and participate in the activation of the TOMS instrument.

TOMS power will be turned on as soon as possible after orbit injection during a pass over a Hydromet ground station equiped to command the TOMS functions. This will occur approximately 3 hours after launch and allows transmission of housekeeping data, insures that TOMS is in a safe-holding state, and warms the instrument and diffusers. NASA and Hydromet will start monitoring TOMS Housekeeping data during the first week starting as soon as possible after TOMS is turned on. NASA personnel will evaluate the instrument performance for a decision on continuing operation of the instrument.

TOMS will then be allowed to outgas for a nominal seven day period before being fully activated. Energizing the photomultiplier tube (PMT) or Mercury Calibration Lamp in the presence of high concentrations of outgassing products could cause potentially damaging corona discharge. On day eight, TOMS high voltage will be turned on and verified, and the science data activated. A TOMS solar irradiance measurement will be performed soon after science data activation and as soon as the sun is within the diffuser field-of-view, as specified by NASA.

5.2.2 Operations

TOMS will normally be controlled using on-board stored commands. Real time commands will be sent to TOMS for initial turn on, special operations, and emergencies. Normal operating command sequences in the form of lists of programmed commands will be prepared by NASA and sent to Hydromet on a regular basis. These will cover a period of 14 days. Hydromet will provide NASA the spacecraft orbit elements in sufficient time for NASA to produce these Two Week Command Lists for the next period. The Two Week Command Lists will include orbit number, time, and corresponding Programmed Commands. Hydromet is responsible for transmission of commands to the Meteor-3 spacecraft.

The timing of these commands is critical and must be agreed upon in general one year before launch, and afterwards, nine days before a specific command list is due. Both sides have developed a joint operation plan of data exchange needed for operations and ozone fields calculations. The joint operation plan specifies agreed upon formats, data rates, schedules, and coordinated operating procedures.

The TOMS requires periodic calibration measurements of the solar irradiance to compute the albedo from irradiance data. This is obtained by commanding the instrument to view a sunlit diffuser plate. Based on measured orbit vector data provided by Hydromet, NASA will compute solar calibration times and include the appropriate commands for viewing the diffuser plate within the Two Week Command Lists.

The TOMS data recorder will record measurements at the instrument sample rate throughout useable portions of the orbit. TOMS science data will be recorded for 13 orbits (= 1 day) and then downlinked at least daily to NASA and Hydromet receiving stations. Hydromet will be responsible for controlling the transmitter. Some housekeeping data is included in the science data. Normal operations will sample all TOMS housekeeping data one orbit every two weeks.

NASA will develop special procedures to prevent gaps in received data. Spacecraft status reporting will be provided by Hydromet and will be monitored by NASA and Hydromet. Emergency procedures will be developed to handle critical out-of-limit conditions. These procedures will be transmitted to Hydromet six months before launch.

TOMS will be left on unless emergency conditions require turn-off. The NASA Mission Operations Manager will be notified at once of any power interruptions or any other Meteor-3 actions that affect TOMS.

Figure 5-1. USSR Site Locations

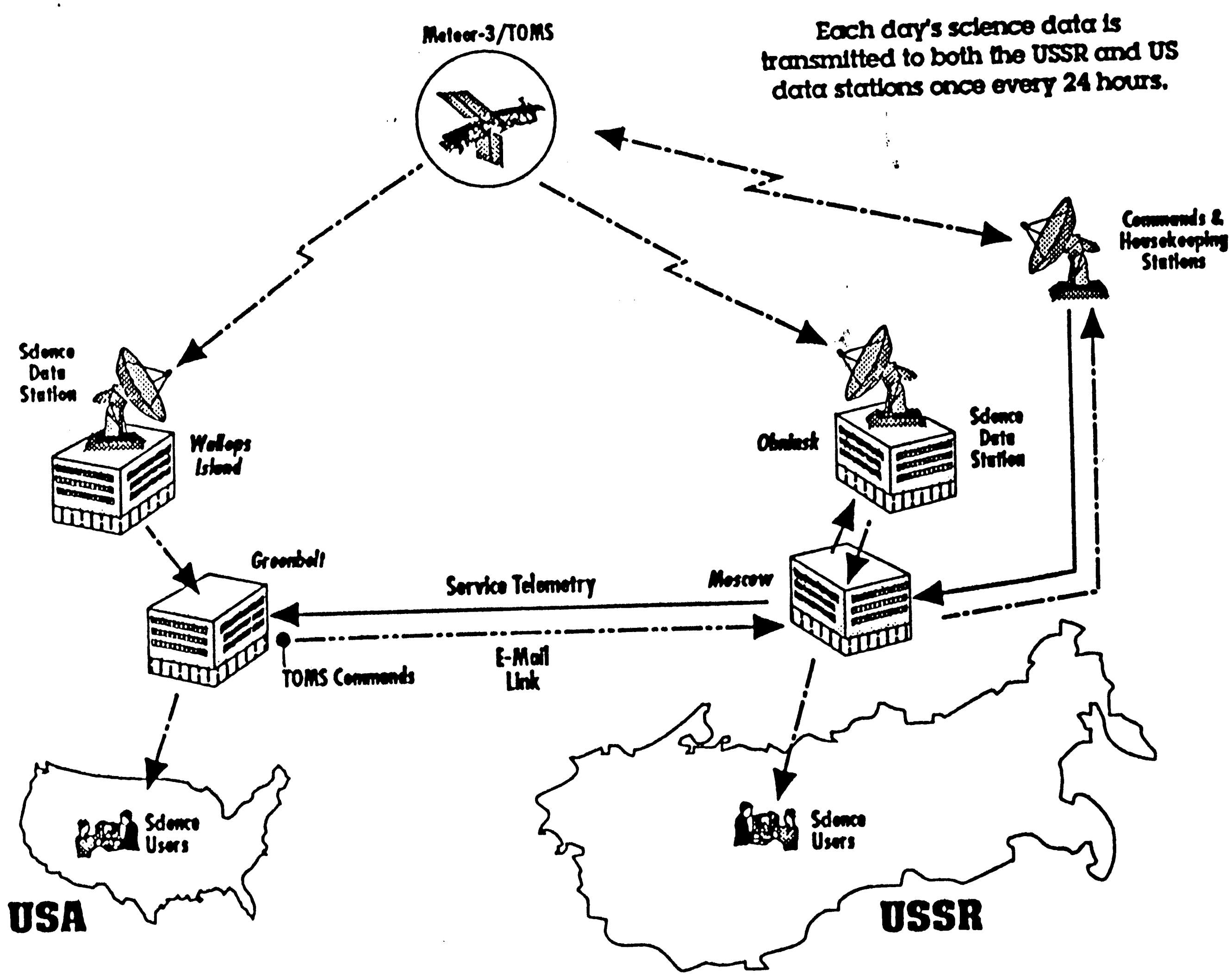


Figure 5-2. Command and Telemetry Flow in Meteor–3/TOMS Mission

6.0 FACILITIES

The US facilities and their functions that are involved in the Meteor-3/TOMS mission are listed below.

Perkin-Elmer, Inc. Pomona, California	• Refurbishment of the TOMS instrument • Development of the diffuser module • Development of the IAM • Final assembly and test
Fairchild Space Germantown, Maryland	• Development of the Data Recorder
NASA/GSFC Greenbelt, Maryland	• Project management • Science data reduction • Instrument operation
GSFC/Wallops Flight Facility Wallops Island, Virginia	• Reception of data from the Meteor-3 spacecraft and transmission to GSFC operations
NASA/NSSDC Greenbelt, Maryland	• Archival of ozone data tapes

In the USSR, Hydromet provides a working area for NASA to use in check-out of TOMS and IAM flight hardware following delivery to the USSR. A source of pressure regulated and flow controlled dry nitrogen gas is provided at all sites where the instrument is being packaged to allow purging of the bag containing the instrument.

7.0 SCHEDULE

The master schedule depicting the major events for the implementation phase of the Meteor-3/TOMS project are shown in Figure 7-1. Updates of schedules are issued periodically and the latest issue of the schedule should be consulted for modifications.

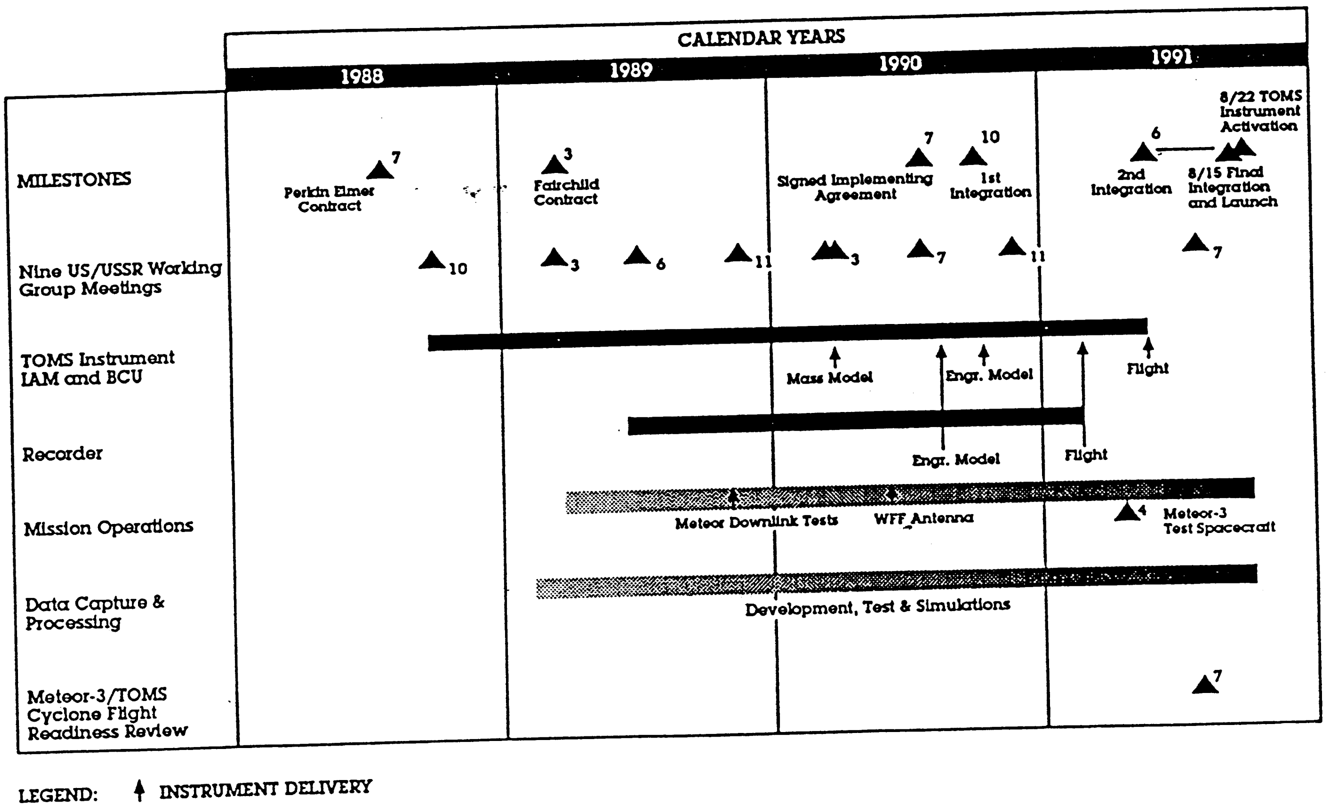


Figure 7-1. Meteor-3/TOMS Mission Development Schedule

8.0 MANAGEMENT

8.1 ORGANIZATION

Figures 8-1 and 8-2 show the TOMS program organization and the Soviet organization associated with the Meteor-3 spacecraft, respectively.

The Associate Administrator for the Office of Space Science and Applications is responsible for the overall direction and evaluation of the Meteor-3/TOMS project. He has assigned Headquarter's responsibility to the Director, Earth Science and Applications Division, who has assigned a Program Manager, Program Scientist and International Affairs Officer. The Program Manager performs the day-to-day program activities at NASA Headquarters and is the key Headquarters focal point working directly with the Project Manager. The Program Scientist is responsible for assuring that the science requirements placed on the project for implementation satisfies program objectives. He is the key focal point of NASA Headquarters related to program science objectives. The International Affairs Officer is responsible for reviewing and approving agreements with the Soviet Union with respect to official US policy.

Within NASA, the GSFC is responsible for project management. The GSFC Project Manager, from the Laboratory for Atmospheres, Code 910, is responsible for assuring the performance of all functions necessary for management of the project. He has full authority to carry out these functions subject to the limitations established by the Director, GSFC. The Project Scientists, from the Atmospheric Chemistry and Dynamics Branch, are responsible for assuring coordination and satisfactory accomplishment of the scientific objectives and the mission.

Management responsibilities and procedures for Meteor-3/TOMS are made in accordance with NASA Management Institute Instruction (NMI) 7120.3, subject: Space Flight Program and Project Management.

8.2 IMPLEMENTATION APPROACH

The USSR Meteor-3 spacecraft and US TOMS instrument are being fabricated independently by each country. Periodic working group meetings, held approximately every four months from mission conception through launch, define the interface and operations between TOMS and Meteor-3. In addition, all other feasible communications media are utilized to help define the interface. These include electronic mail, facsimile, telex, and diplomatic pouch carrier.

NASA is responsible for providing the following hardware:

- TOMS FM-2 Instrument Assembly
- Interface Adapter Module (IAM) including on-board data storage
- Mass-Dimensional Model of the Instrument Assembly and IAM
- Ground Support Equipment
- Connectors to Meteor-3 electrical harness
- Cables to attach the Instrument Assembly to the IAM

NASA also provides documentation on the interface characteristics of TOMS and a flight operation plan.

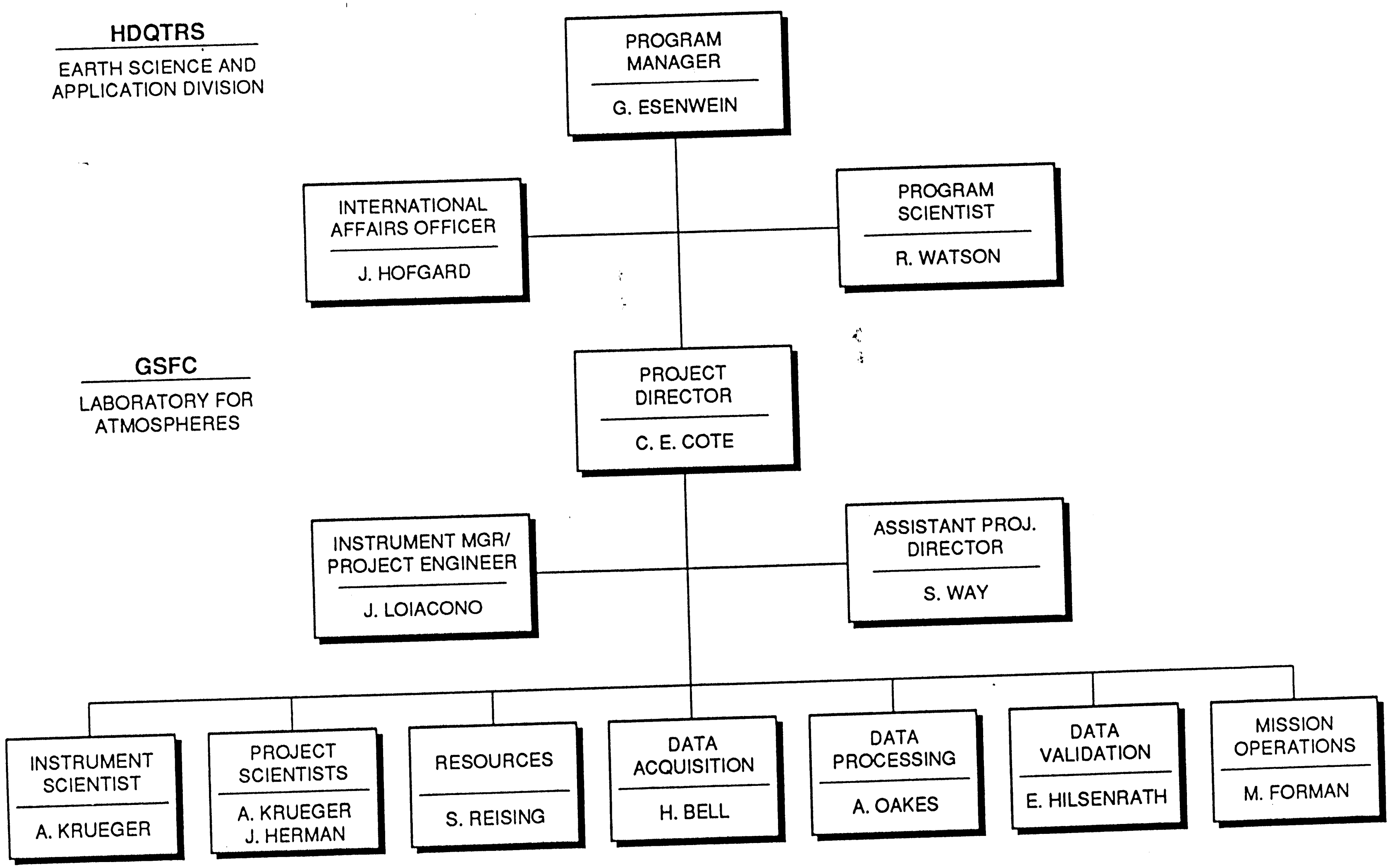


Figure 8-1. TOMS Program Organization

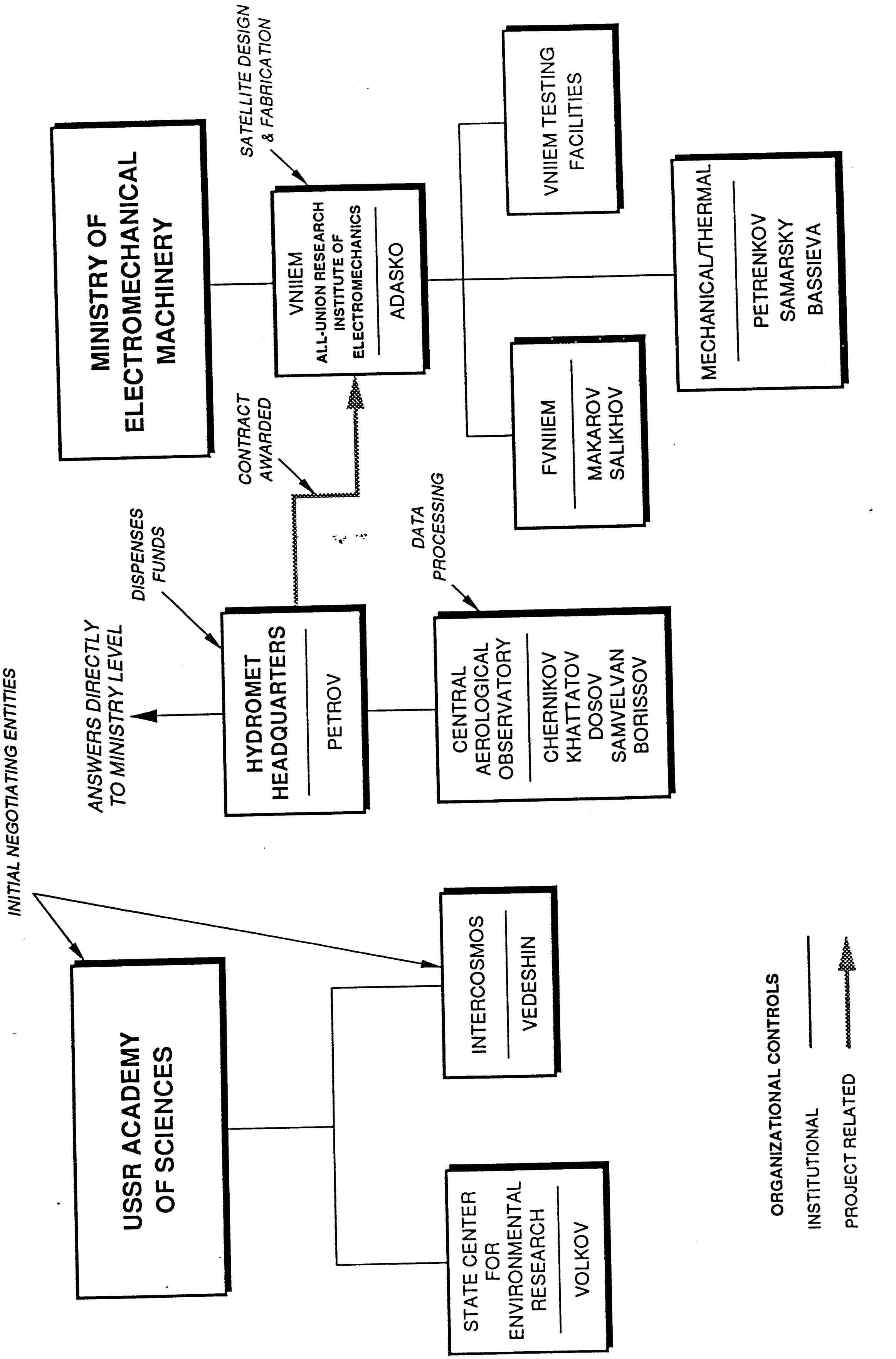


Figure 8-2. Meteor–3 Organization

Flight hardware provided by Hydromet includes the spacecraft and all on-board facilities required to operate TOMS, such as power, timing, and commanding of instrument modes by stored and realtime commands, and transmitting TOMS science data. Hydromet also provides documentation on specifications for pre-launch, launch, and on-orbit conditions; drawings of the spacecraft at attachment points for TOMS, and all relevant operating parameters; and a working area for NASA to use in check-out of TOMS flight hardware following delivery to the USSR.

Spacecraft integration is being conducted in two phases. In phase one, the TOMS and IAM will be tested for interface compatibility with the Meteor-3. Upon completion of phase one, all flight and test equipment will be returned to the US. In phase two, a final check out will be completed at the integration facility in Istra, USSR. Upon arrival at the launch site, final integration of the TOMS on Meteor-3 will take place.

During instrument integration and preparation for launch, NASA personnel are permitted to have direct access to the test connector of the instrument to conduct any necessary tests in order to insure proper function of TOMS. NASA personnel are provided with immediate access to all instrument output data resulting from any test being conducted while TOMS is integrated with the spacecraft. NASA is permitted to attach and operate source illumination fixtures to the integrated instrument at appropriate points in the test sequence for instrument radiometric stimulation. NASA provides a test and integration plan for all phases of integration.

8.3 TEST AND EVALUATION

The TOMS will undergo a full sequence of tests as defined by an environmental and calibration test plan. These tests include subassembly tests, in-process tests, specification compliance tests, orbit simulation tests, environmental (vibration and thermal/vacuum) tests, and device qualification tests. All of the testing will be performed at the sensor manufacturers facility in accordance with established procedures. During these tests, baselines are established for the TOMS against which bench acceptance tests (BAT) will be performed after the TOMS leaves the factory.

After arrival at the spacecraft integration facility, BAT tests are performed at various stages to insure that the TOMS still meets the performance and functional specifications. A special BAT fixture and support equipment travels with TOMS to provide the appropriate radiation stimulus and interface simulation. The various data outputs and house-keeping telemetry are evaluated and recorded to check the well-being of the sensor and provide a history of the sensor performance.

TOMS will be brought to the USSR twice for spacecraft integration and test before the Meteor-3/TOMS launch. The first integration connects TOMS to the Meteor-3 spacecraft. These tests confirm the electrical functionality of the Meteor-3/TOMS interface. This integration also verifies the specifications for mechanical interface and for electromagnetic interference both produced by TOMS and to which TOMS is susceptible. TOMS is returned to NASA after first integration for qualification and acceptance testing.

The second integration will integrate TOMS on the Meteor-3 spacecraft following NASA provided test and integration procedures. These tests include the tests outlined for the first integration. Also, the spacecraft will undergo vacuum testing, during which time the TOMS instrument will be removed from the spacecraft to prevent contamination of the instrument.

NASA personnel are present at all times during any testing and integration activities involving the TOMS Instrument Assembly or IAM. When the TOMS Instrument Assembly or IAM are on the Meteor-3 spacecraft, Hydromet will conduct testing necessary for mechanical and electrical integration using only NASA-written commands and with NASA personnel present. No testing of either the Instrument Assembly or IAM will take place without the presence and consent of NASA personnel.

If repair or recalibration should become necessary, the TOMS Instrument Assembly and IAM will be returned to the United States.

NASA personnel will supervise the accuracy of the positioning of the TOMS Instrument Assembly and IAM on the Meteor-3 spacecraft. Once final integration of the TOMS on the Meteor-3 spacecraft is finished, NASA personnel will witness the fairing closure over the spacecraft and the launch.

8.4 PROCUREMENT STRATEGY

The Meteor-3/TOMS instrument is being procured by the Goddard Space Flight Center from the Perkin-Elmer Corporation. The contract was awarded on a sole source basis because of the short time constraints and small number of experienced contractors able and willing to refurbish an existing engineering model TOMS instrument to flight qualification status. The selection of the Perkin-Elmer Corporation was based on the experience of their personnel with the Nimbus-7 TOMS instrument. A Request for Proposal was released resulting in a Mission Study Contract and Hardware Contract within a twelve month period. This contract provides for delivering a flight model of the TOMS instrument, an Interface Adaptor Module (IAM), and a data recorder to the spacecraft by September 1990. The master schedule for this activity is shown in Figure 7-1.

The design is based on the refurbishment and minor enhancement of the Engineering Model from the highly successful TOMS instrument previously flown on the Nimbus Project. The most significant changes from Nimbus-7 TOMS program are the addition of a diffuser plate assembly, as described in Section 4.1.2.1, and the use of the IAM, described in Section 4.1.2.3. It is anticipated that the performance of the instrument will equal or exceed the original Nimbus-7 TOMS instrument.

8.5 PROGRAM REVIEWS AND REPORTS

Within NASA, a series of systematic, technically oriented, reviews will be conducted in accordance with "The GSFC Design Review Program," GMI 8010.1B. These reviews will be administered by the Office of Flight Assurance (OFA) and a chairman selected from the Systems Review Office. A series of management oriented reviews will be conducted in accordance with "The GSFC Project Managers Handbook," GHB 7150.1B.

Between NASA and the USSR, periodic working group meetings will be convened approximately every four months from mission conception through launch. The purpose of these will be to define the interface and operations between TOMS and Meteor-3.

A Management Information System will be implemented to serve as a basis for monitoring and reporting technical, resource, and schedule performance to provide Center and Headquarters management with an accountability of project status and progress.

As soon as possible after launch, the Project Manager and Project Scientist will jointly produce a documentary report that will include the final mission technical report and preliminary scientific assessment of the project results. Significant scientific theories, procedures, techniques, and results will be discussed. Resource data will also be included.

9.0 RESOURCES

Tables 9-1 and 9-2 provide the monetary and manpower budgets, respectively, for the Meteor-3/ TOMS project through the first sixty days of mission operations. After sixty days of flight operations, budget support will be via UPN 665, Mission Operations and Data Analysis.

Table 9-1
Meteor-3/TOMS Project budget ($1000) for development launch, and first sixty days of mission operations

ITEM	FY88	FY89	FY90	FY91	FY92	TOTAL
TOMS, IAM, GSE, & Engineering Support Meetings & Integration	2,196	2,843	6,776	3,133	127	15,075
Flight Memory	0	460	852	584	0	1,896
Data Processing, Mission Operations, Command Mgmt., & Science Support	0	8	740	441	262	1,451
Project & Engineering Support, Meetings, etc.	104	293	1,300	1,350	428	3,475
Total	2,300	3,604	9,668	5,508	817	21,897

Table 9-2
Meteor-3/TOMS Project Civil Service manpower budget (equivalent man years) for development launch, and first sixty days of mission operations

ITEM	FY88	FY89	FY90	FY91	FY92	TOTAL
Total Civil Service Manpower	0.7	6.0	8.2	5.4	0	20.3

10.0 NASA-HYDROMET IMPLEMENTATION AGREEMENT

Subsequent to the Reagan-Gorbachov summit agreement in April 1987, NASA Headquarters and the State Committee for Hydrometeorology (Hydromet) began development of the *Meteor-3/ TOMS Implementing Agreement between the National Aeronautics and Space Administration of the United States of America and the State Committee for Hydrometeorology of the Union of Soviet Socialist Republics*, delineating the activities and responsibilities of NASA and Hydromet for the Meteor-3/TOMS mission. Specific areas addressed in this document include:

- Data Exchange
- Hardware
- Security Requirements
- Transportation
- Integration
- Launch
- On-orbit operation

This agreement was signed on July 25, 1990 and entered into force by an exchange of diplomatic notes on August 24, 1990.

11.0 POSTSCRIPT

Meteor-3/TOMS was successfully launched on schedule on August 15, 1991 from the formerly secret Plesetsk Cosmodrome. TOMS activation was completed on August 23, 1991. To date, all TOMS operations have been normal and excellent measurements are being returned.

12.0 REFERENCE DOCUMENTS

The following documents are formally controlled by the authoring organizations. All of these documents are available to Hydromet.

(1) *Meteor-3/TOMS Implementing Agreement between the National Aeronautics and Space Administration of the United States of America and the State Committee for Hydrometeorology of the Union of Soviet Socialist Republics*, signed July 25, 1990

(2) *Electrical Interface Control Document, Interface Adapter Module to Meteor-3 Spacecraft and TOMS Instrument*, Perkin-Elmer, Document No. 358701

(3) *Hardware Requirement Specification, Bench Checkout Unit, GSFC/TOMS FM-2/IAM*, Perkin-Elmer, Document No. 230015

(4) *Interface Configuration, TOMS FM-2*, Perkin-Elmer, Drawing No. 358505-002

(5) *Mechanical Interface Control Drawing (ICD), IAM*, Perkin-Elmer, Drawing No. 358705-002