STATUS OF U.S. DEEP SPACE MISSIONS
AND
THE ROLE OF ADVANCE TECHNOLOGY FOR THE FUTURE

by

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ABSTRACT

This presentation covers deep space missions currently flying and those planned in the next decade. Those flying include Voyager, Galileo, and NEAR. Future missions to be discussed include: Cassini, Mars Pathfinder and the Mars Surveyor Program leading to a sample return mission in 2005; the New Millennium technology demonstration series of flights, the Stardust Discovery Mission; Pluto Express, and the Origins Science Theme which includes interferometers for detecting and ultimately imaging planets around nearby stars, and the Next Generation Space Telescope.

VOYAGER

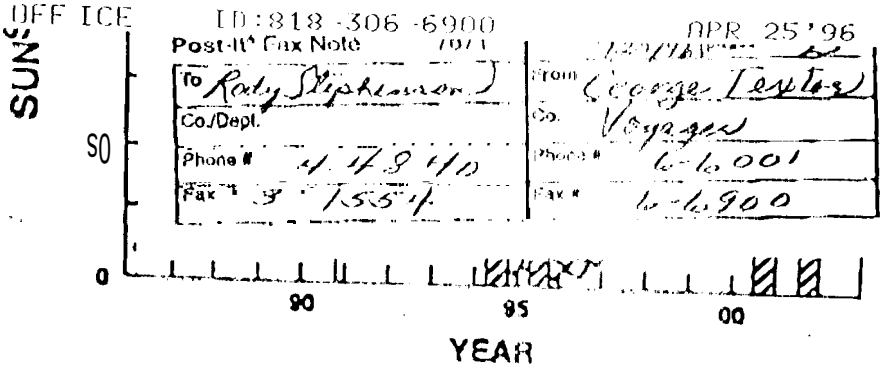


Fig. 16 Ulysses mission relative to solar activity cycle. (Estimated values after 1993).

titudes and positions of Voyager 1 and 2 and of Pioneer 10 and 11 can be found in s 17 and 18. A detailed description of Voyager instruments can be found in /35/ and of r 10 instruments in /36/. On board resources are sufficient to keep Pioneer 10 operating ower sharing) till 1998 and Voyager 1 and 2 till around 2015.

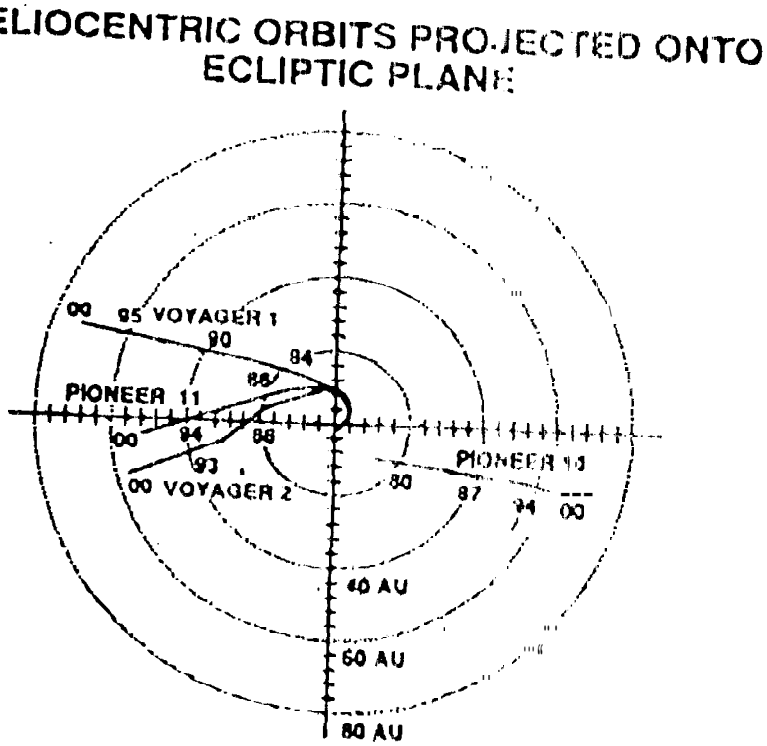
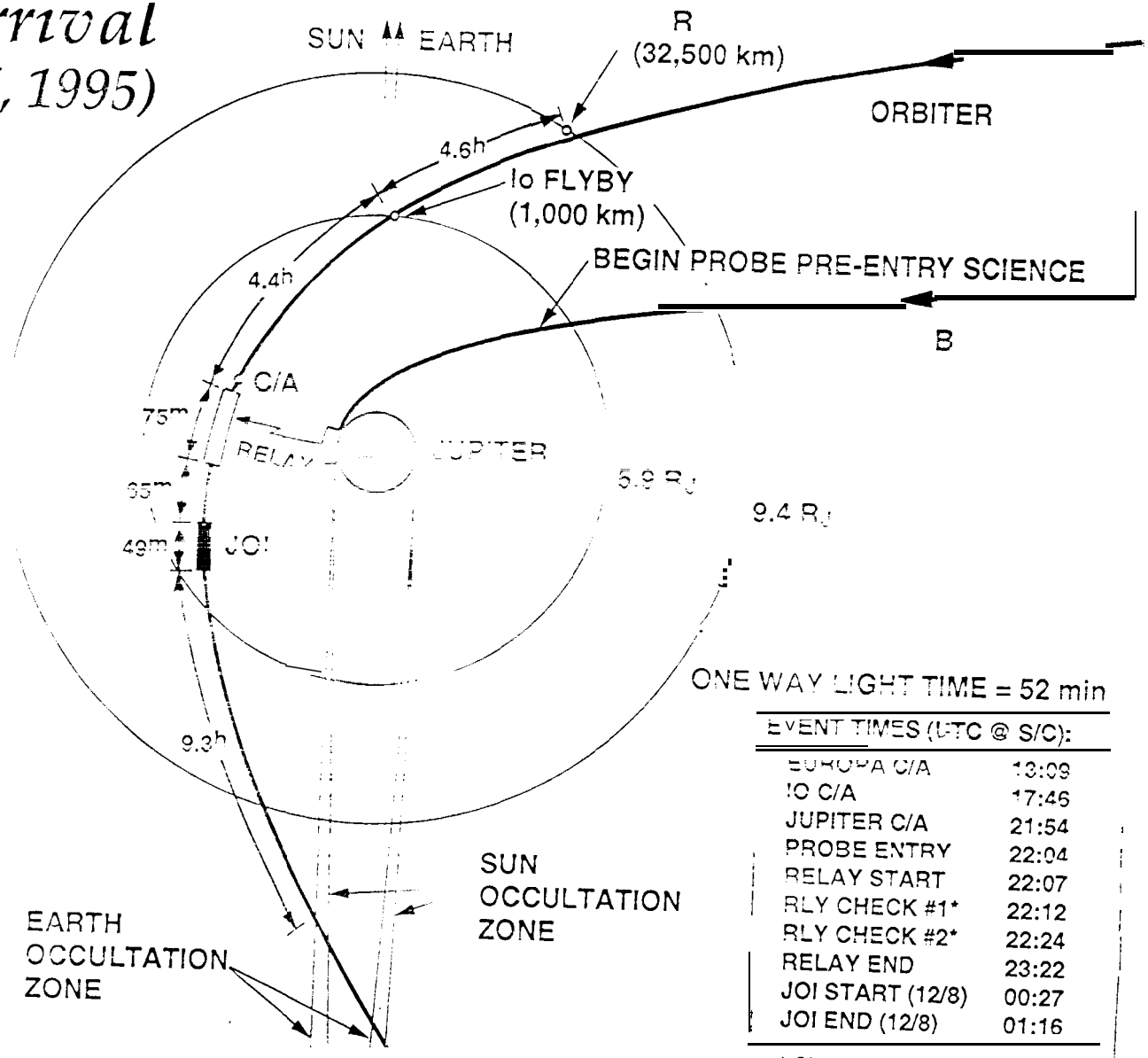


Fig. 17 Positions of Pioneer 10 and 11 and of Voyager 1 and 2.

GALILEO

Jupiter Arrival
(December 7, 1995)

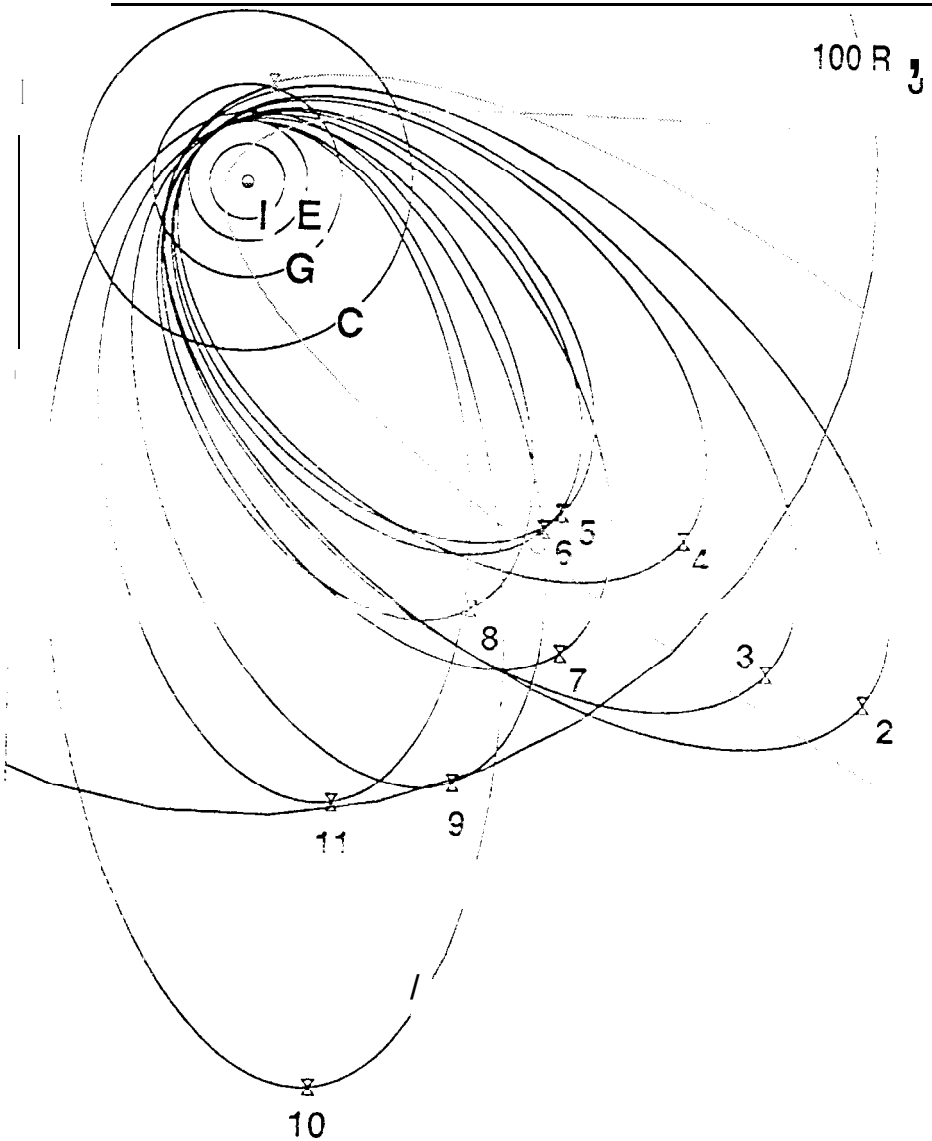


ONE WAY LIGHT TIME = 52 min

EVENT TIMES (UTC @ S/C):	
EUROPA C/A	13:09
IO C/A	17:46
JUPITER C/A	21:54
PROBE ENTRY	22:04
RELAY START	22:07
RLY CHECK #1*	22:12
RLY CHECK #2*	22:24
RELAY END	23:22
JOI START (12/8)	00:27
JOI END (12/8)	01:16

* CHECKS IF RVCR IN LOCK

ORBITAL **TOUR OF THE JUPITER SYSTEM**



I 10

E = EUROPA

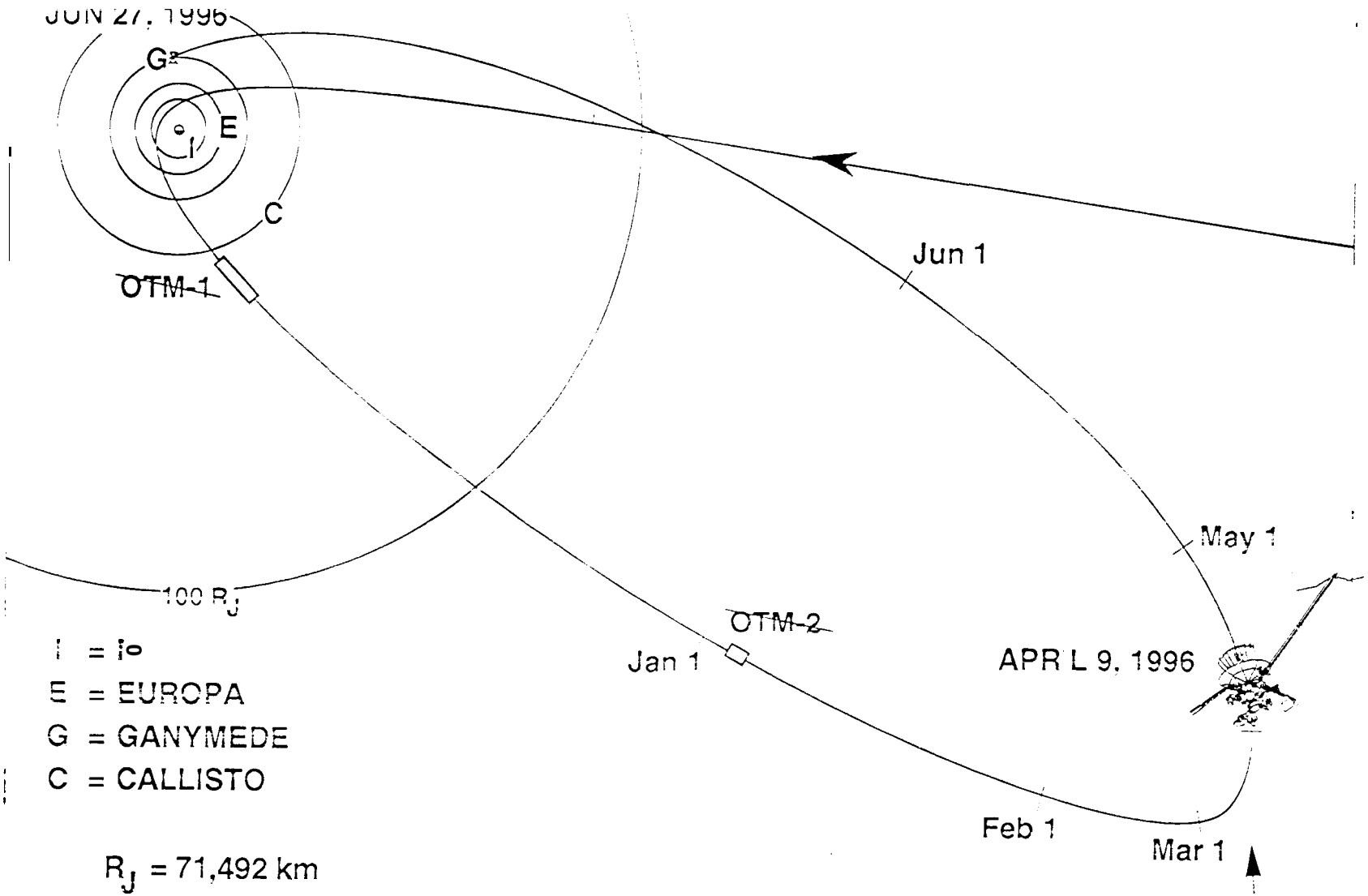
G = GANYMEDE

C = CALLISTO

G1	27	Jun	96
G2	5	Sep	96
C3	4	Nov	96
E4	19	Dec	96
E6	20	Feb	97
G7	5	Apr	97
G8	7	May	97
C9	25	Jun	97
Cl 0	17	Sep	97
E11	6	Nov	97

R_J = 71.492 km

GALILEO'S FIRST ORBIT OF JUPITER



MAXIMUM DISTANCE (APOJOVE) = 50 TIMES EARTH-MOON DISTANCE

Probe Science Summary

- Probe entered jovian atmosphere near southern edge of so-called "infrared hot spot", believed to be a region of reduced clouds on Jupiter.

- Ratio of helium to hydrogen in jovian atmosphere found to be close to value in the Sun, in contrast to that on Saturn which is highly depleted.

- Jovian atmosphere relatively dry - much less water than expected on basis of solar composition and predictions.

- Heavy elements carbon, nitrogen, sulfur are significantly enriched with respect to solar composition. Implications for planetary formation.

- Some rare gases, such as neon highly depleted. Others, such as krypton and xenon, highly enriched relative to solar composition. Isotopic ratios near solar ratios. Implications for planetary formation and evolution.

- Strong winds (several hundred miles per hour) persist deep below cloud levels. Implies heat escaping from jovian interior drives winds.

- Optically thick (optical depth greater than unity) cloud or haze, probably ammonia cloud, detected near beginning of probe descent. Another distinct cloud layer observed below, but it is tenuous by Earth standards. Second cloud likely to be ammonium hydrosulfide cloud.

- Much less lightning activity on Jupiter per unit area than on Earth. Individual events about 10 times more energetic.

- New intense radiation belt discovered between Jupiter's ring and uppermost atmospheric layers.

- Upper atmospheric temperatures much greater than expected, those in lower atmosphere close to expectations.

Galileo ISSUES

CHECK VALVE

- WITH OX CHECK VALVE OPEN, FUEL CHECK VALVE STAYS AT "CRACKING" POINT (ABOUT TO OPEN NORMALLY)

- ANY INCREASE IN PROPELLANT TANKS TEMPERATURE CAUSES HELIUM CONVECTION OF OX VAPOR TO FUEL SIDE

- ELECTRICAL POWER MARGIN, WHICH IS (HARDWIRE) SHUNTED TO PROPELLANT TANK HEATERS, IS BEING MAINTAINED ESSENTIALLY CONSTANT TO AVOID CONVECTION--I.E., PROPELLANT TEMPERATURE IS BEING HELD CONSTANT

- POTENTIAL FOR ENERGETIC (HARMFUL) REACTION OF PROPELLANTS IN PRESSURIZATION SYSTEM IS EXTREMELY LOW. NONETHELESS, ALL REASONABLE STEPS ARE BEING TAKEN TO MINIMIZE ANY PROPELLANT MINGLING

Our #1 Problem Now Is:

Understanding the Tape Recorder anomalies and developing the proper usage constraints and requirements to ensure reliable operation

WJO
3/13/96

Galileo
DMS STATUS

- THE GALILEO DMS WORKED FLAWLESSLY DURING ALL ARRIVAL-DAY ACTIVITIES

- THE DMS CONTINUES TO FUNCTION PROPERLY FOR ALL PROBE DATA PLAYBACK ACTIVITIES

  - NO DATA HAS BEEN LOST/INTERRUPTED BECAUSE OF A DMS PROBLEM

- CONTRARY TO OUR EARLIER BELIEF, RECENT DMS CONDITIONING ACTIVITIES ON THE SPACECRAFT SHOWED THE DMS CAN STICK IN LESS THAN 2 sec AFTER TAPE STOPS AND FOLLOWING THE MINIMUM SPEED (7.68Kbps) OPERATION. THIS COUPLED WITH PREVIOUS DATA SUGGESTS THE TAPE CAN STICK AT ANY LOCATION AFTER OPERATING AT HIGH OR LOW SPEED

- THE 7.68Kbps STICK COMPLETELY INVALIDATES OUR CURRENT DMS USAGE STRATEGY THAT IS BASED ON NO STICKING AFTER A 7.68Kbps COOLDOWN OPERATION

- RE-EXAMINATION OF DMS USAGE STRATEGY IN THE G1 ENCOUNTER SEQUENCE IS IN PROCESS

WJO
3/18/96

Galileo
DMS STATUS cont

- GROUND TESTING CONTINUES USING THE GEOTAIL AND MAGELLAN FLIGHT SPARE UNITS; ADDITIONAL FLIGHT TESTING IS BEING PLANNED
- AN ODETICS BRASSBOARD UNIT (GEOTAIL) WAS OPERATED FOR THE FIRST TIME IN FIVE YEARS -- THE TAPE STUCK!
- THE MAGELLAN FLIGHT SPARE WAS OPERATED FOR THE FIRST TIME IN THREE YEARS -- THE TAPE STUCK!
- THE MAGELLAN AND GALILEO TAPE WAS MANUFACTURED FROM THE SAME LOT
- THE GALILEO DUMMY ERASE HEAD STICK MODEL IS STILL THE ONLY SINGLE FAULT MODEL THAT EXPLAINS THE FLIGHT SYMPTOMS. WHY AND HOW IS TBD
- THE ANOMALY TEAM CONTINUES TO WORK VIGOROUSLY WITH SUPPORT FROM ODETICS. THE TEAM REPORTS TO THE PROJECT MANAGER REGULARLY
- ASIDE FROM A RANDOM FAILURE, CURRENT DATA SUGGEST THERE ARE NO CREDIBLE THREATS TO THE DMS FUNCTIONING THROUGH THE ENTIRE TOUR ASSUMING IT IS USED CONSISTENT WITH YET TO BE APPROVED FLIGHT RULES/CONSTRAINTS
- DMS WORKSHOP IS BEING HELD AT JPL ON MARCH 20 AND 21

WJO
3/18/96

Galileo

DMS STATUS

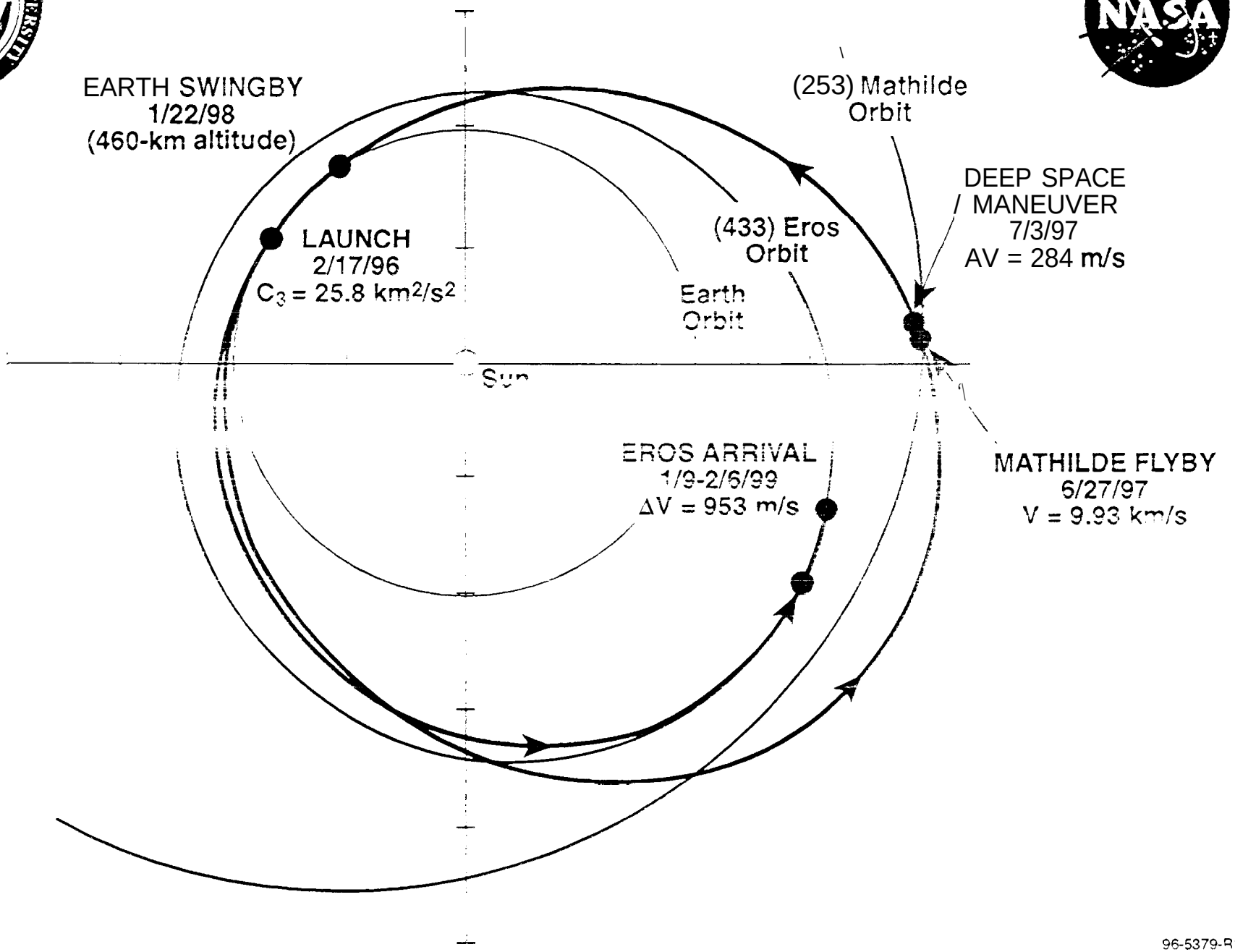
DMS WORKSHOP STATUS/PLANS

- A TWO-DAY WORKSHOP WILL BE HELD AT JPL ON MARCH 20 AND 21, 1996
  - INDEPENDENT REVIEW/ASSESSMENT
  - IDENTIFY ISSUES/ITEMS OVERLOOKED/INCOMPLETE
  - SUGGEST METHODS TO USE THE RECORDER MORE RELIABLY
- WORKSHOP MEMBERS INCLUDE A CROSS-SECTION REPRESENTING:
  - TRANSPORT DESIGNERS/ELECTRONICS AND MECHANICAL DESIGNERS
  - TAPE MANUFACTURING AND CHEMISTRY EXPERTS
  - USERS - FLIGHT AND GROUND
- WORKSHOP PERSONNEL (~ 30 PEOPLE) ARE FROM:
  - AEROSPACE INDUSTRY (LM, AEROSPACE CORP, LORAL)
  - INDUSTRY (AMPEX, SONY, ODETICS, 3M)
  - OTHER NASA CENTERS (GSFC, LRC, MSFC)
  - UNIVERSITIES (CIT)
  - PRIVATE CONSULTANTS
  - JPL
  - GLL STANDING REVIEW BOARD

NOTE: ESA AND JAPANESE REPRESENTATIVES WERE REQUESTED BUT DECLINED BECAUSE OF LACK OF DIRECT EXPERIENCE/INTIMATE KNOWLEDGE

NEAR

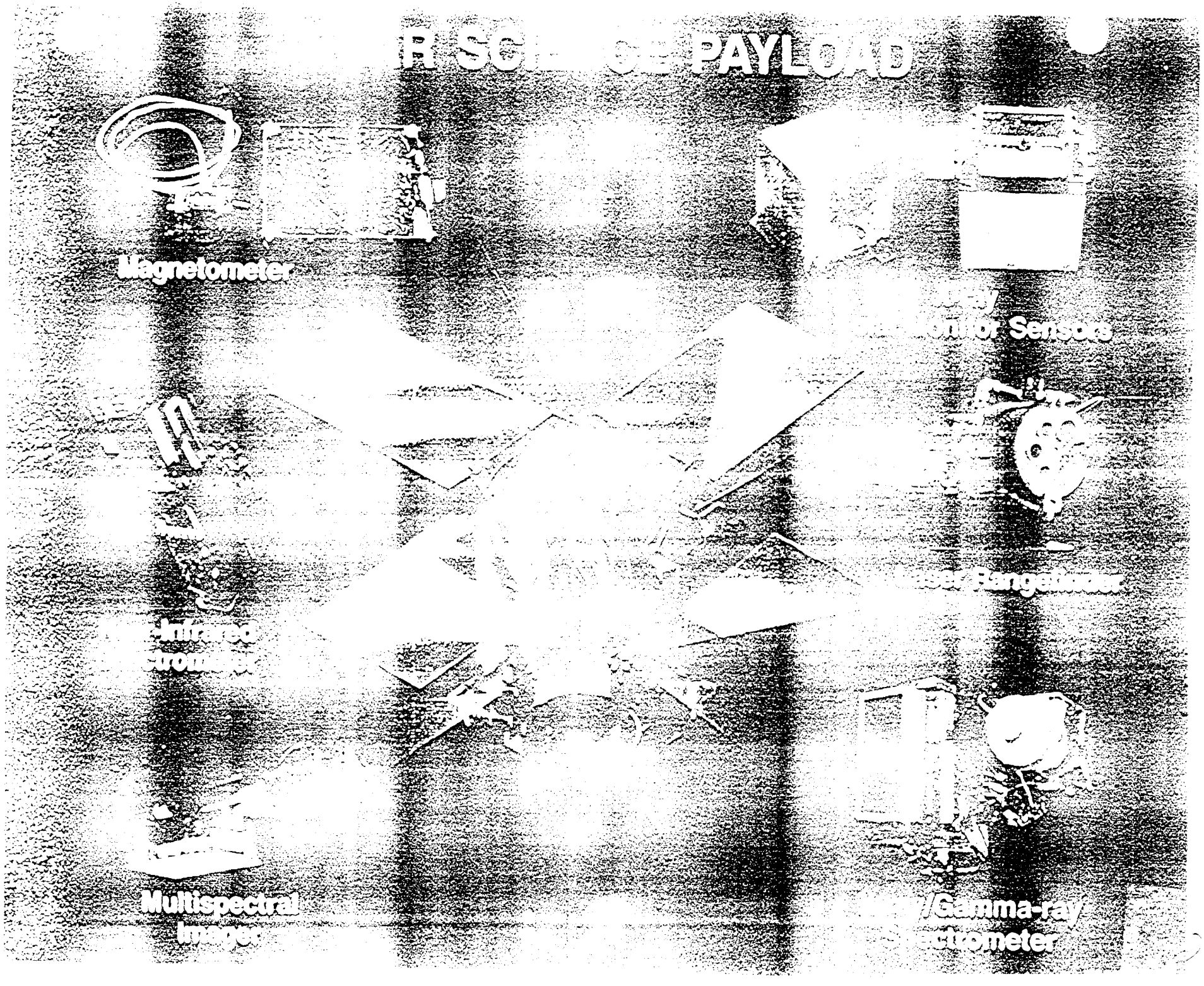
NEAR Trajectory Profile



96-5379-R1

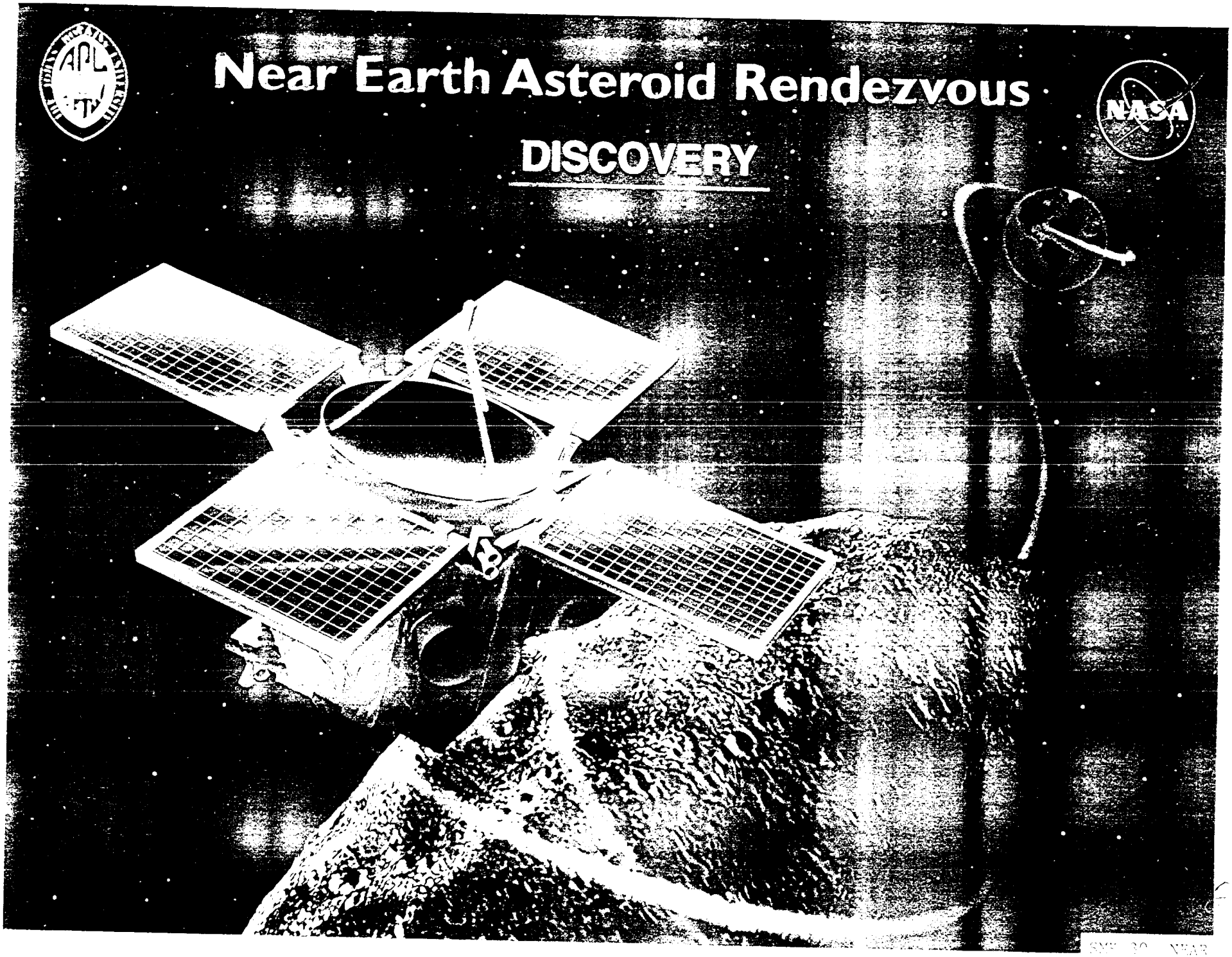
NEAR Spacecraft

- Highly redundant, solar-powered, 3-axis stabilized
- Fixed antennas, solar panels, and instruments
- Dry mass 467 kg, 56 kg instruments, Δv 1450 m/s
- Launch vehicle Delta II 7925-8
- 1.9-Gbit solid state recorder capacity
- X-band link at 2.944 - 26.496 kbps
- Accurate pointing of instruments:
  - Attitude know edge to 50 μr, control to 1.7 mr
  - Attitude stability to 50 μr over 1 second


R SC CE PAYLOAD
Magnetometer
Multispectral
Gamma-ray

Near Earth Asteroid Rendezvous

DISCOVERY

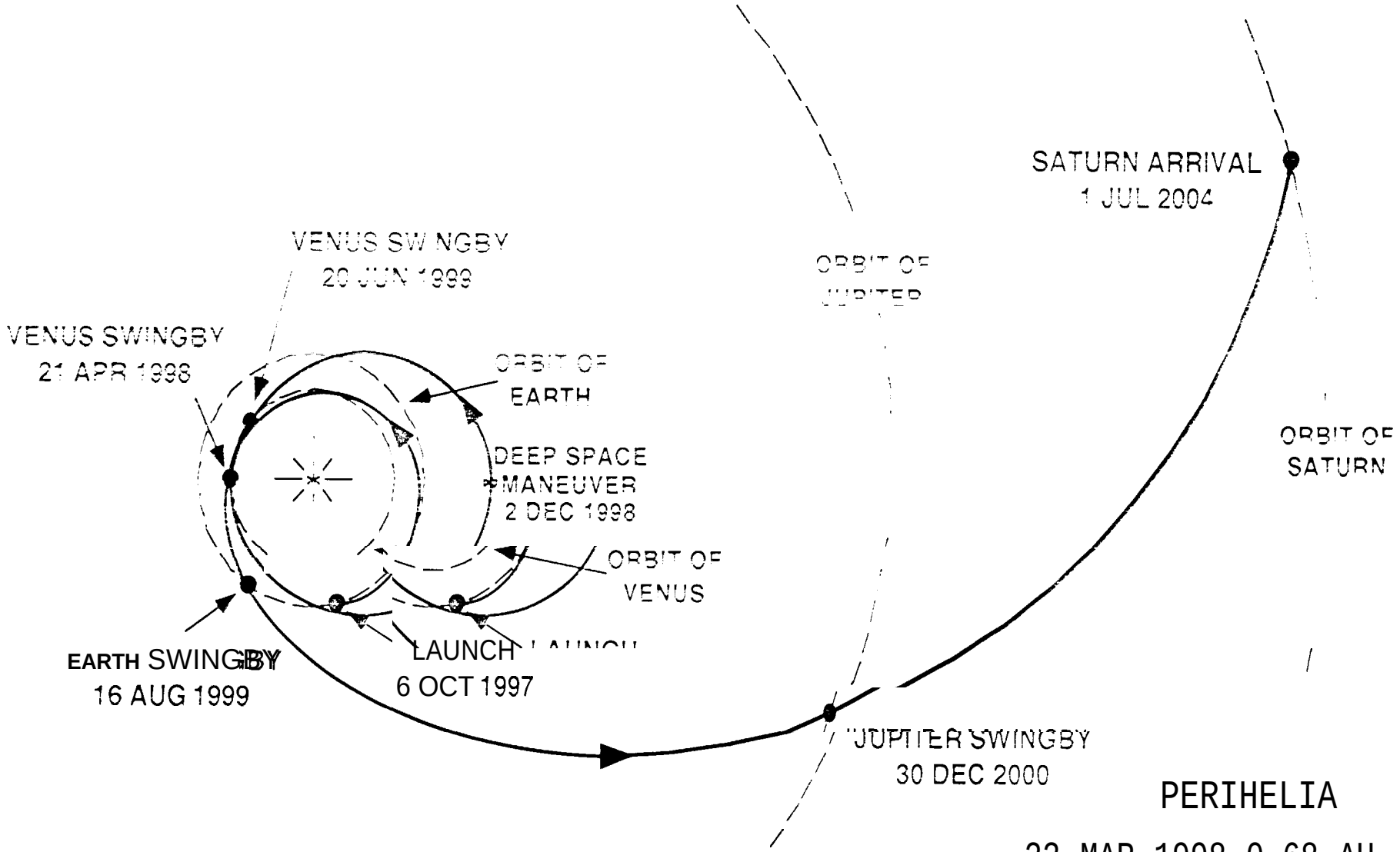


SMT 30 NEAR

CASSINI

CASSINI - VVEJGA OCT 1997

INTERPLANETARY TRAJECTORY



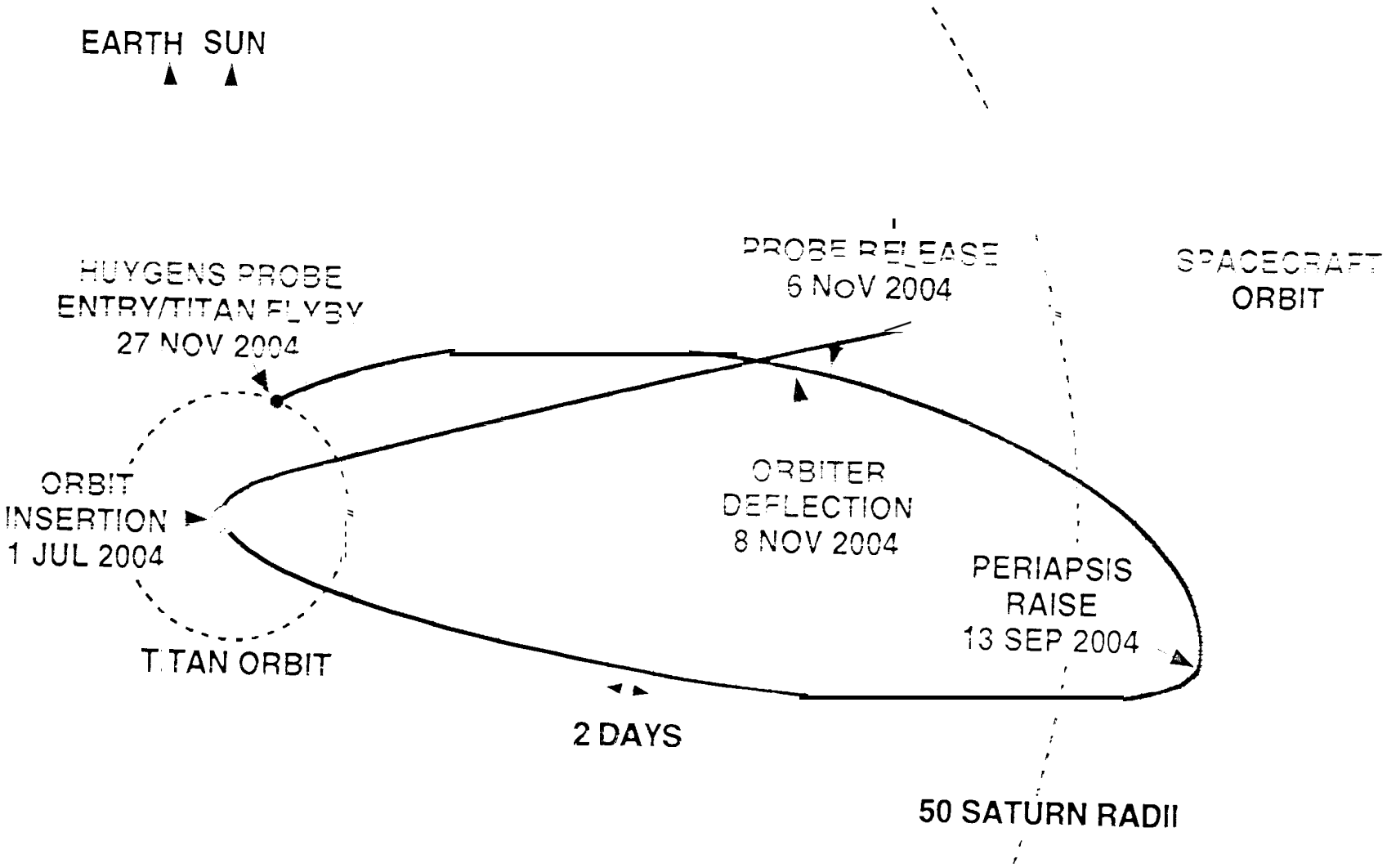
PERIHELIA

23 MAR 1998 0.68 AU
27 JUN 1999 0.72 AU

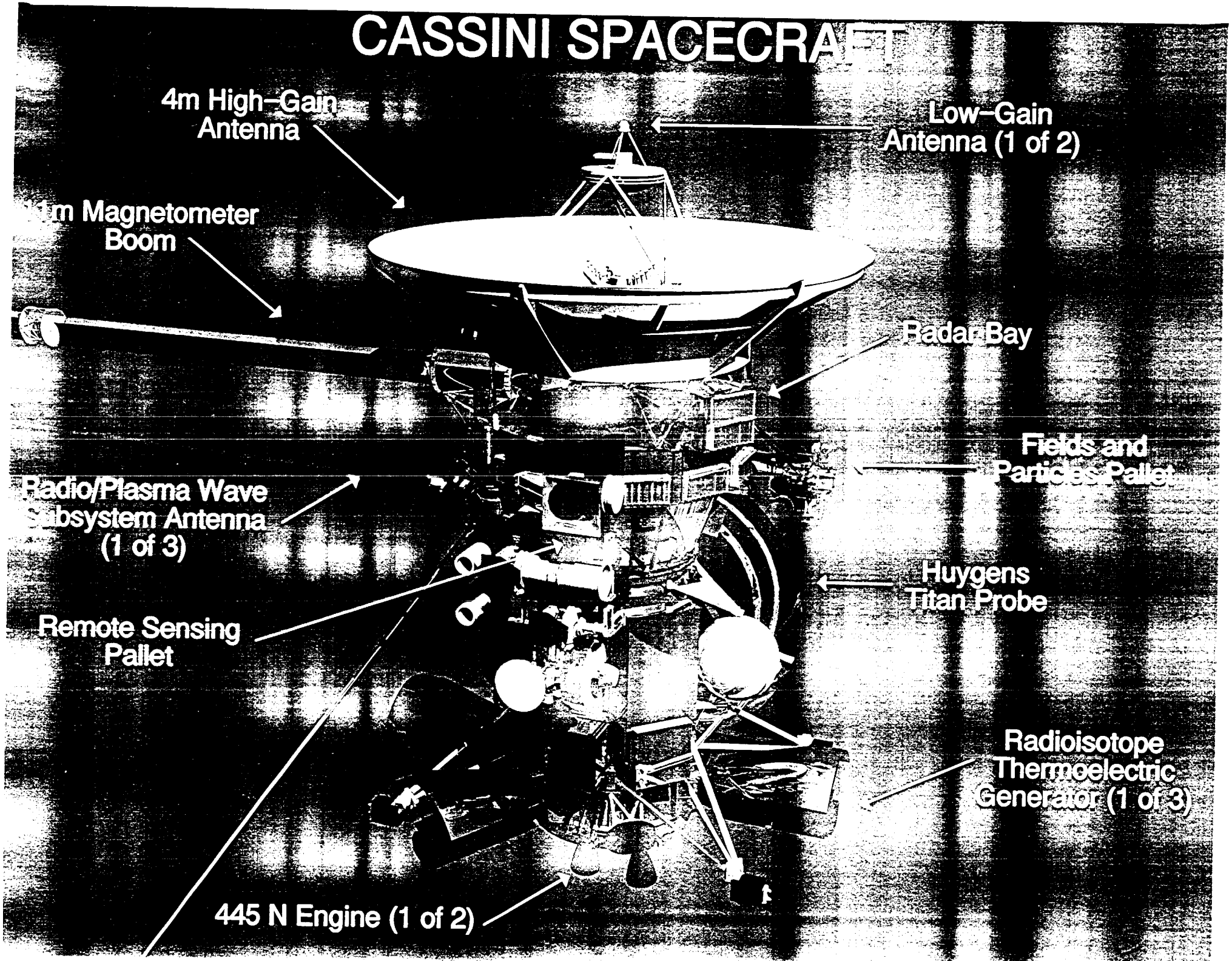
CASSINI - VVEJGA OCT 1997

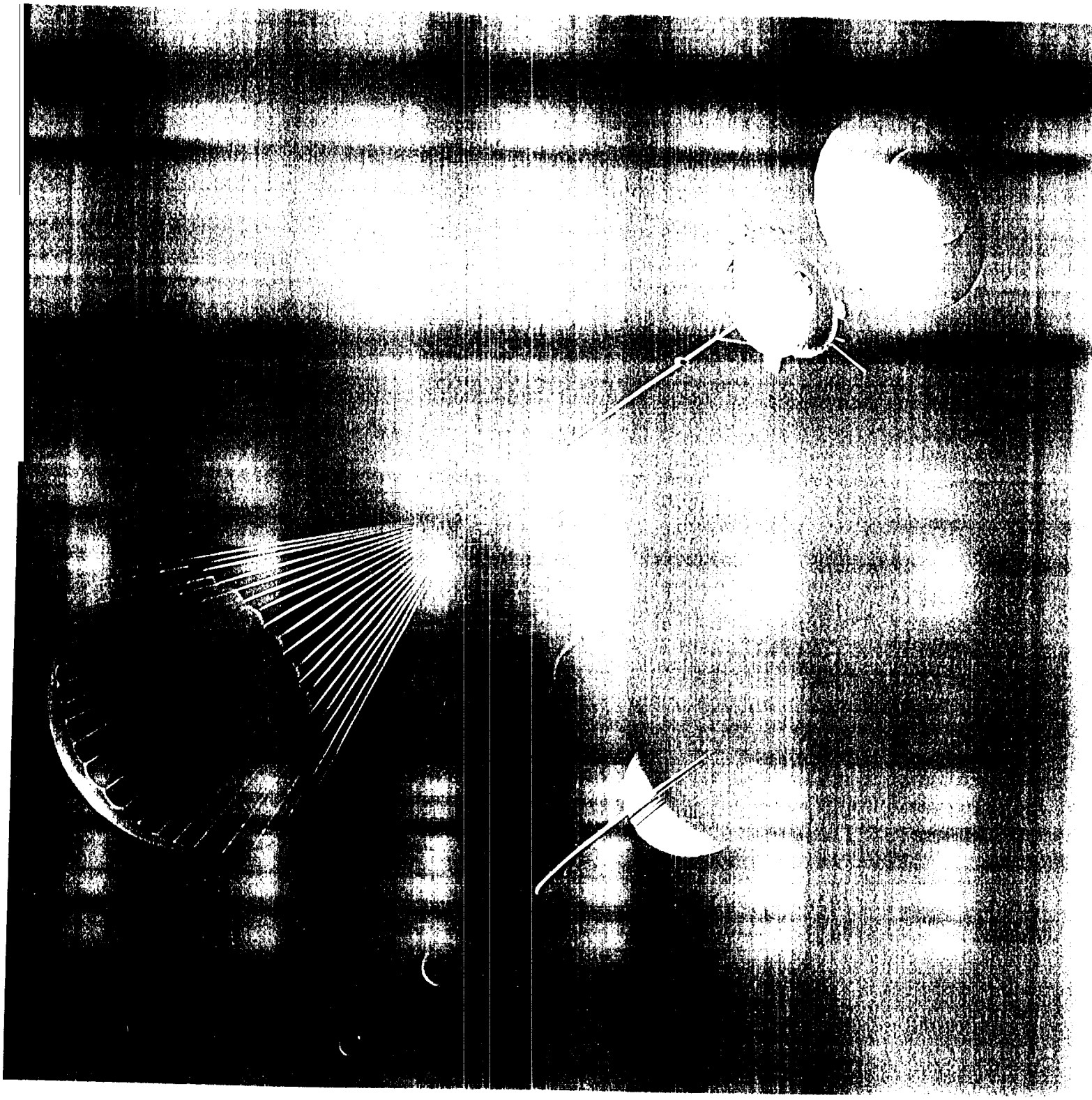
SATURN ARRIVAL AND INITIAL ORBIT

VIEW FROM SATURN NORTH POLE



CASSINI SPACECRAFT





JPL

CASSINI RADAR

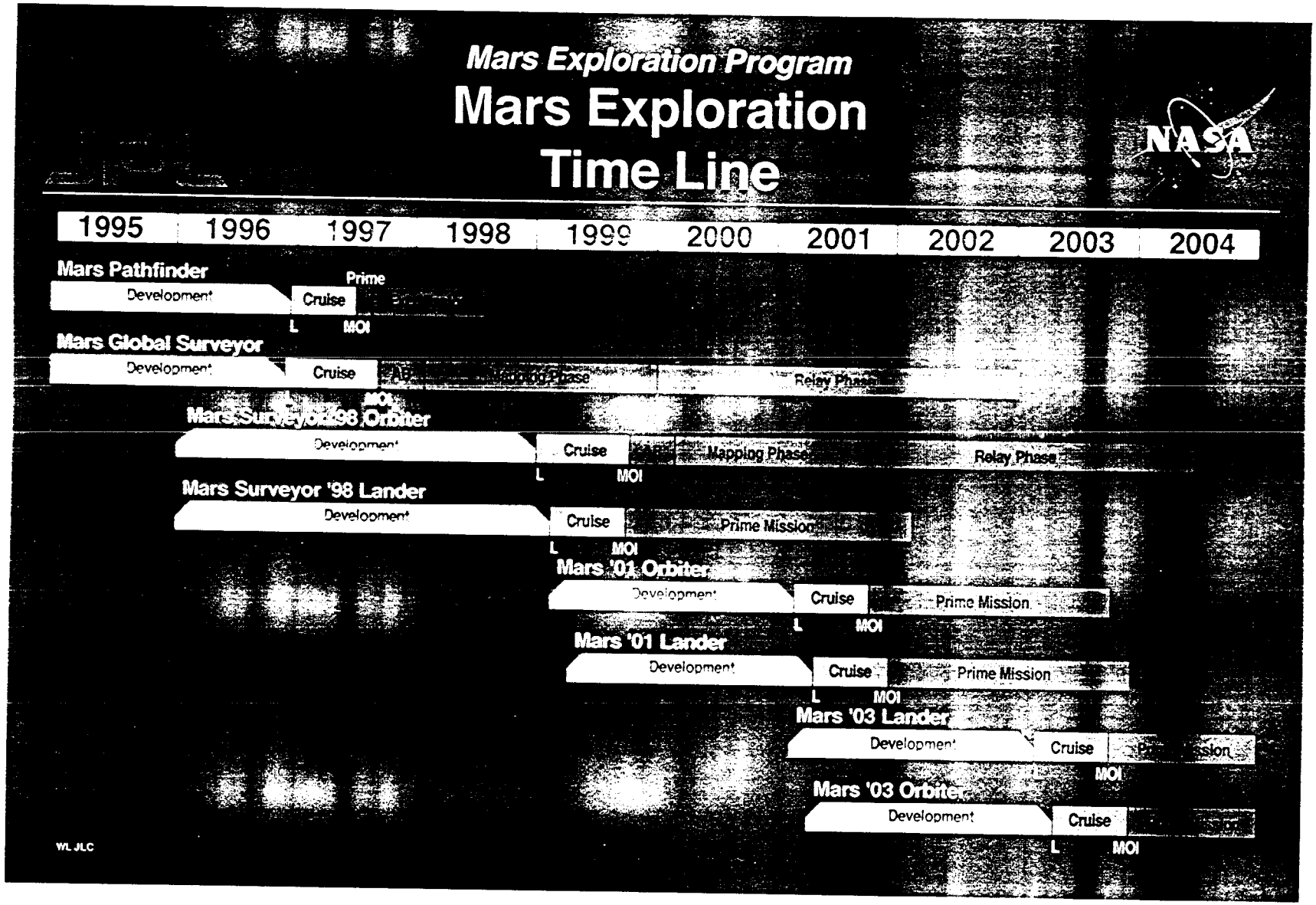
CAPABILITY

- SURFACE IMAGING
- ALTIMETER
- RADIOMETER
- SCATTEROMETER

TARGETS

- TITAN
- ICY SATELLITES
- SATURN

MARS PROGRAM

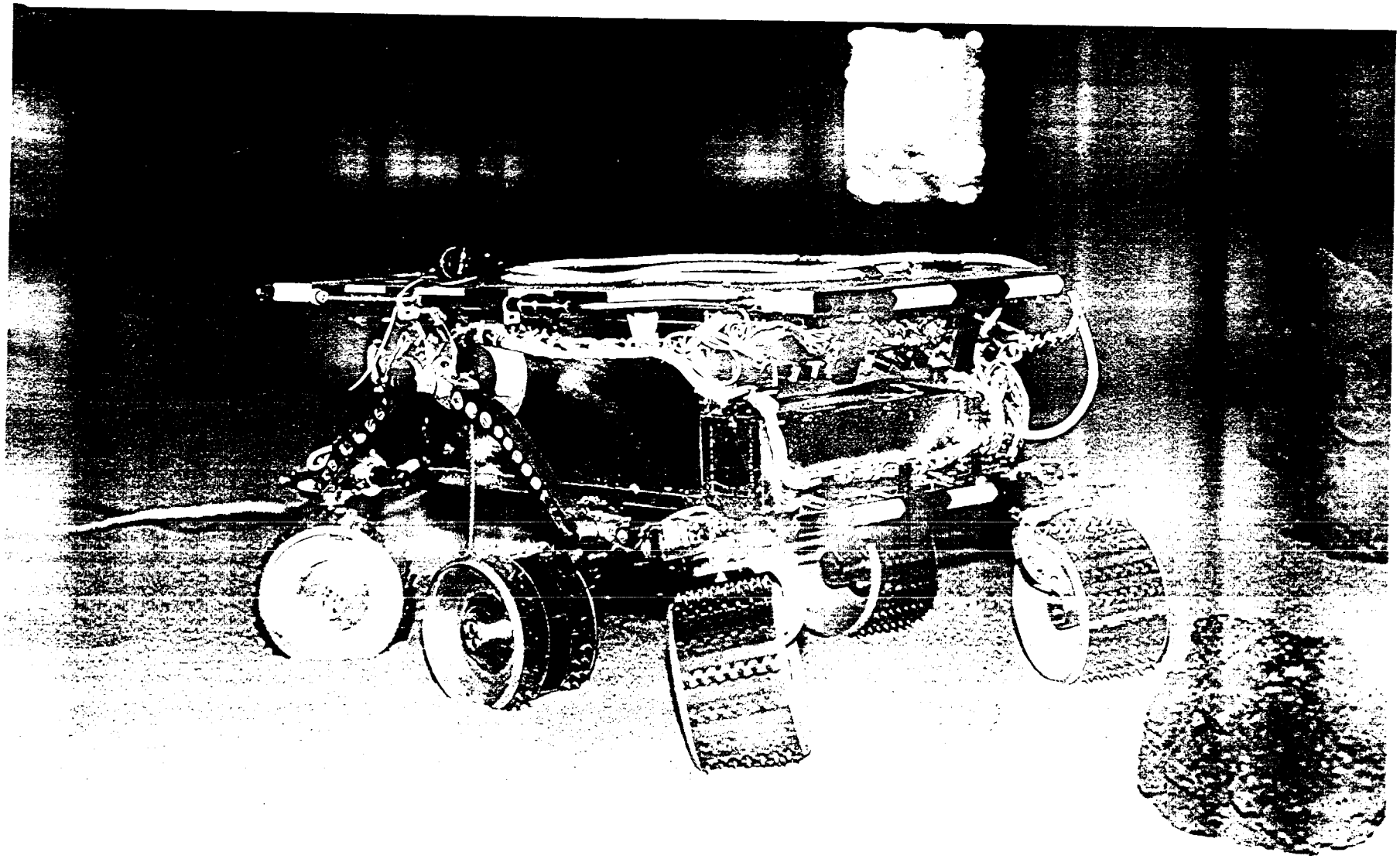

Mars Exploration Program
Mars Exploration Time Line
NASA
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Mars Pathfinder
Development
Cruise
Prime
L
MOI
Mars Global Surveyor
Development
Cruise
Mapping Phase
Relay Phase
Mars Surveyor '98 Orbiter
Development
Cruise
Mapping Phase
Relay Phase
L
MOI
Mars Surveyor '98 Lander
Development
Cruise
Prime Mission
L
MOI
Mars '01 Orbiter
Development
Cruise
Prime Mission
L
MOI
Mars '01 Lander
Development
Cruise
Prime Mission
L
MOI
Mars '03 Lander
Development
Cruise
MOI
Mars '03 Orbiter
Development
Cruise
L
MOI
WL JLC

MARS PATHFINDER

AVIATION WEEK
& SPACE TECHNOLOGY
A PUBLICATION OF THE McGRAW-HILL COMPANIES
APRIL 22, 1996

PATHFINDER PREPARING FOR MARS

PAGE 56



MARS GLOBAL SURVEYOR

Mars Global Surveyor Project

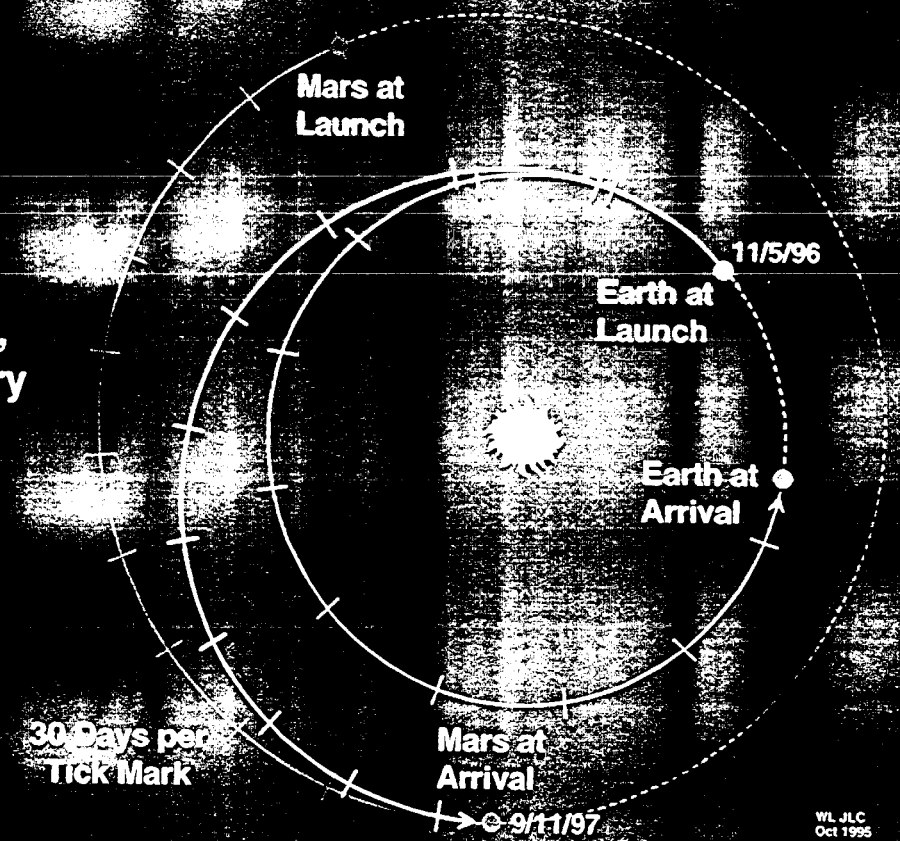
Roadmap From Earth to Mars

Launch Period:	05 Nov 1996 to 25 Nov 1996
Arrival Period:	11 Sep 1997 to 22 Sep 1997
Time to Reach Mars:	301 to 310 Days, Type 2 Trajectory
Distance Flown:	800 Million km (approximate)

Mars Orbit

Earth Orbit

MGS Trajectory

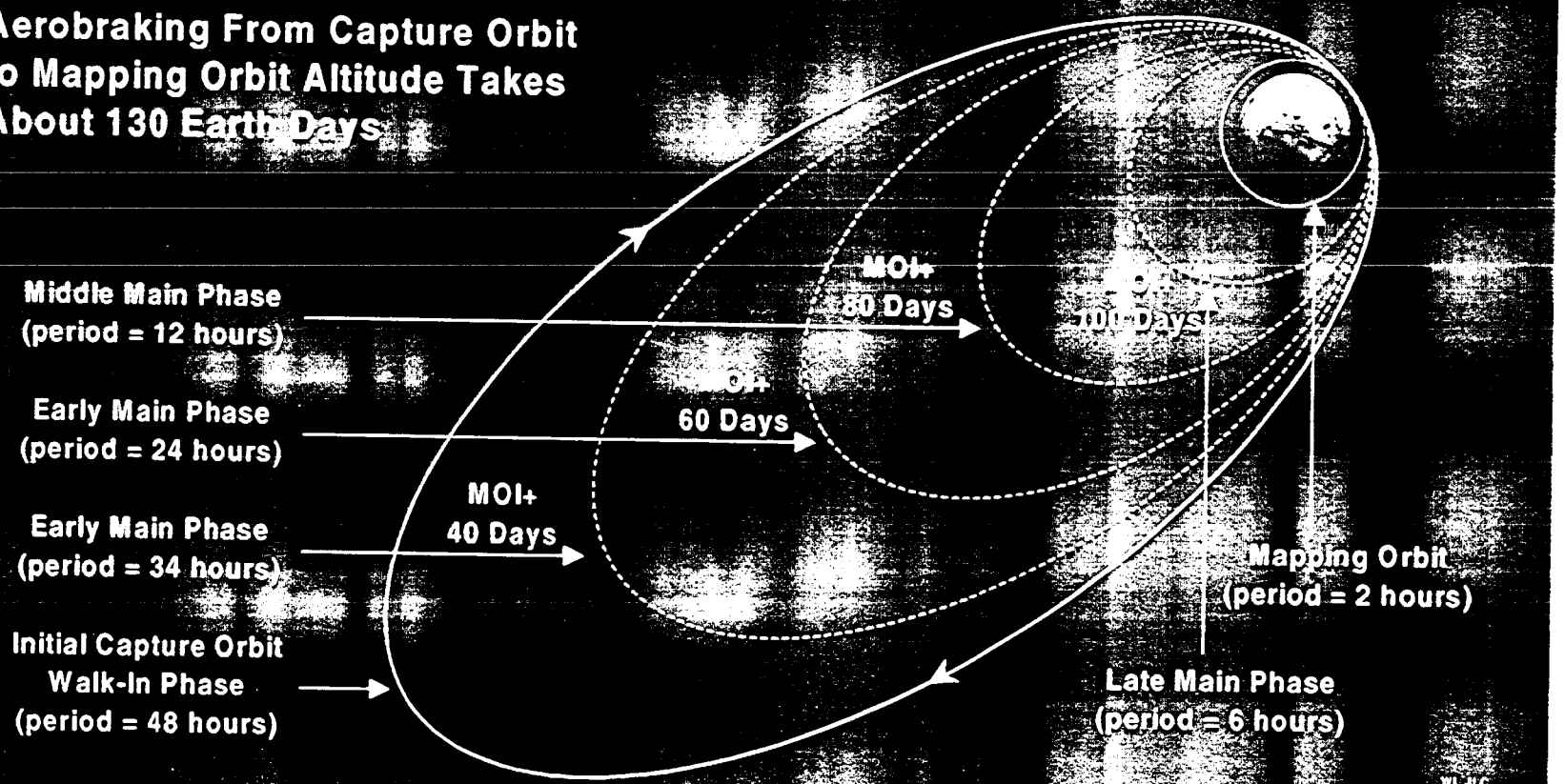


WL JLC
Oct 1995

Mars Global Surveyor Project

MGS Aerobrake Baseline Profile

Aerobraking From Capture Orbit to Mapping Orbit Altitude Takes About 130 Earth Days

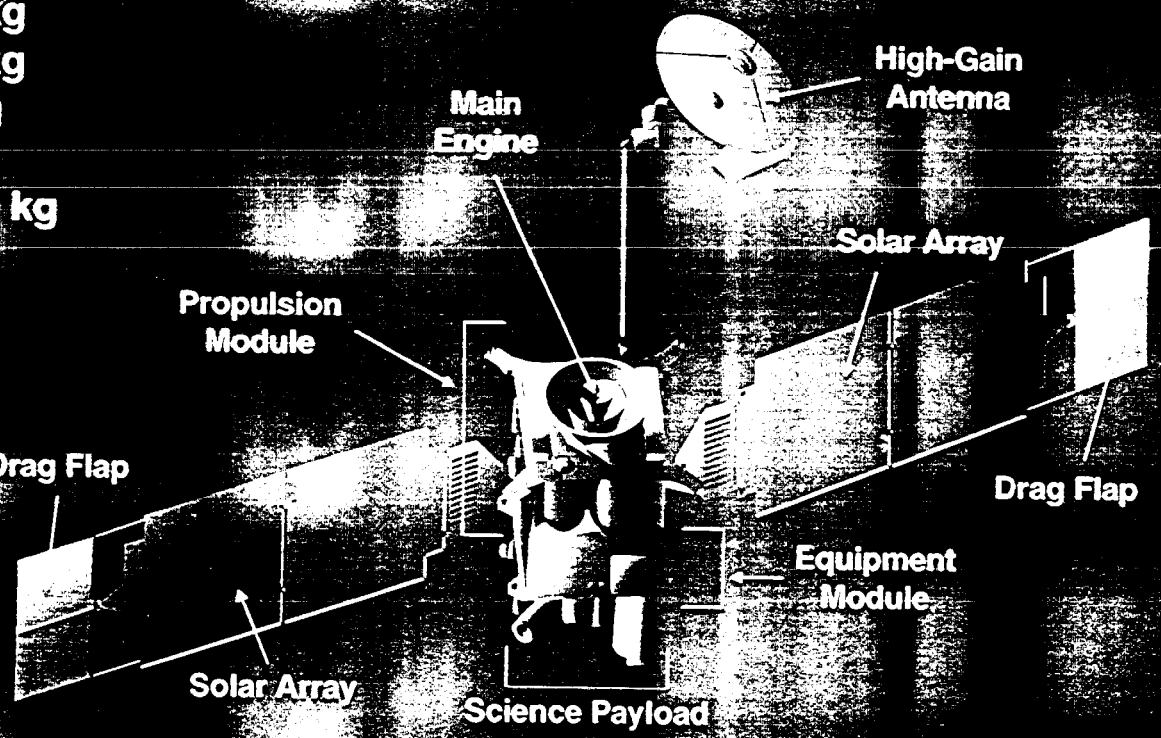


WL JLC
May 1995

Mars Global Surveyor Project

MGS Spacecraft In Mapping Configuration

Structure Mass:	595 kg
Propellant Mass:	380 kg
Payload Mass:	75 kg
Total Mass:	**1,050 kg**



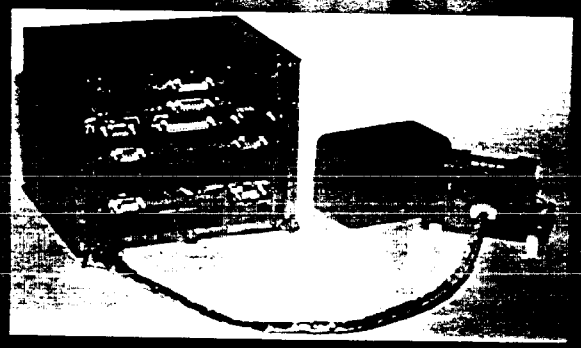
Science Payload:

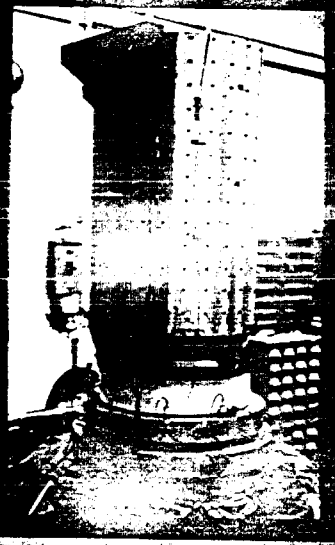
Electron Reflectometer
Magnetometer
Mars Orbiter Camera
Mars Orbiter Laser Altimeter
Mars Relay Radio System
Radio Science
Thermal Emission Spectrometer

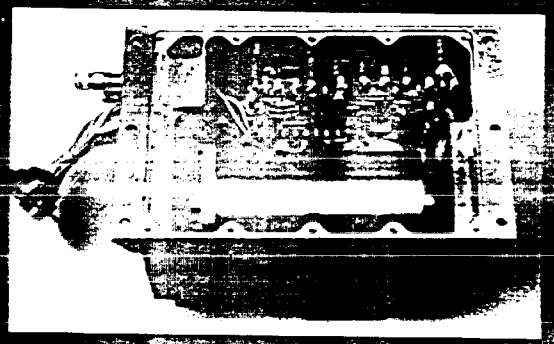
WL JLC DAS
Dec 1995

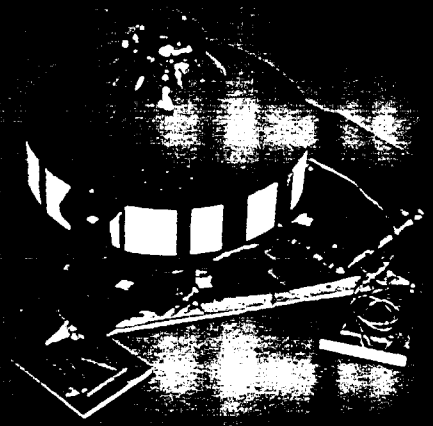
Mars Global Surveyor Project

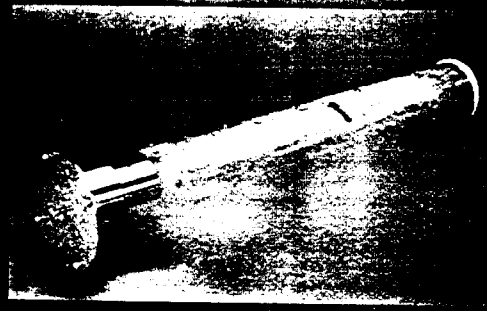
Science Instruments

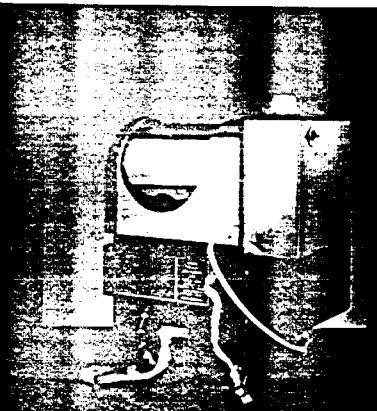






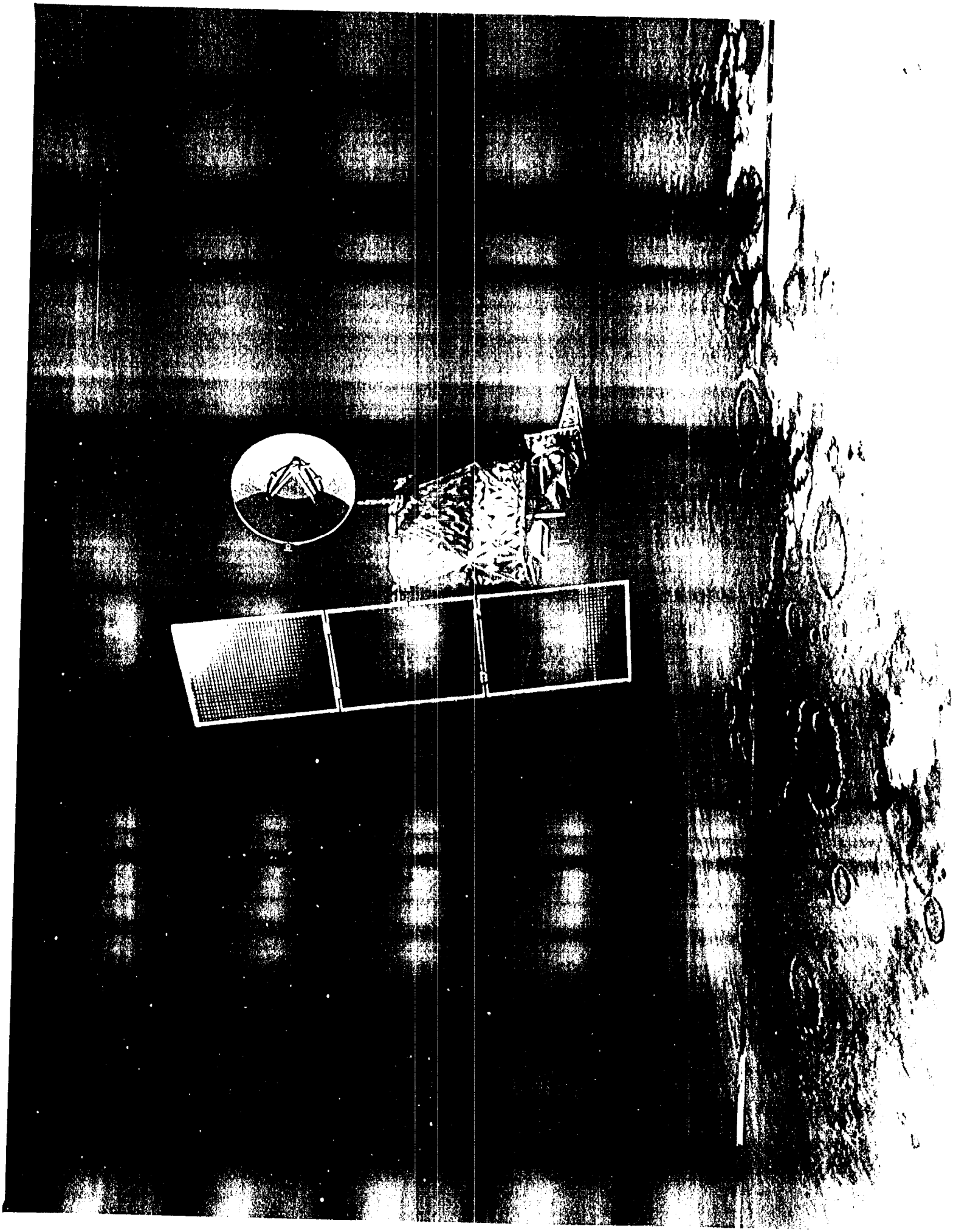


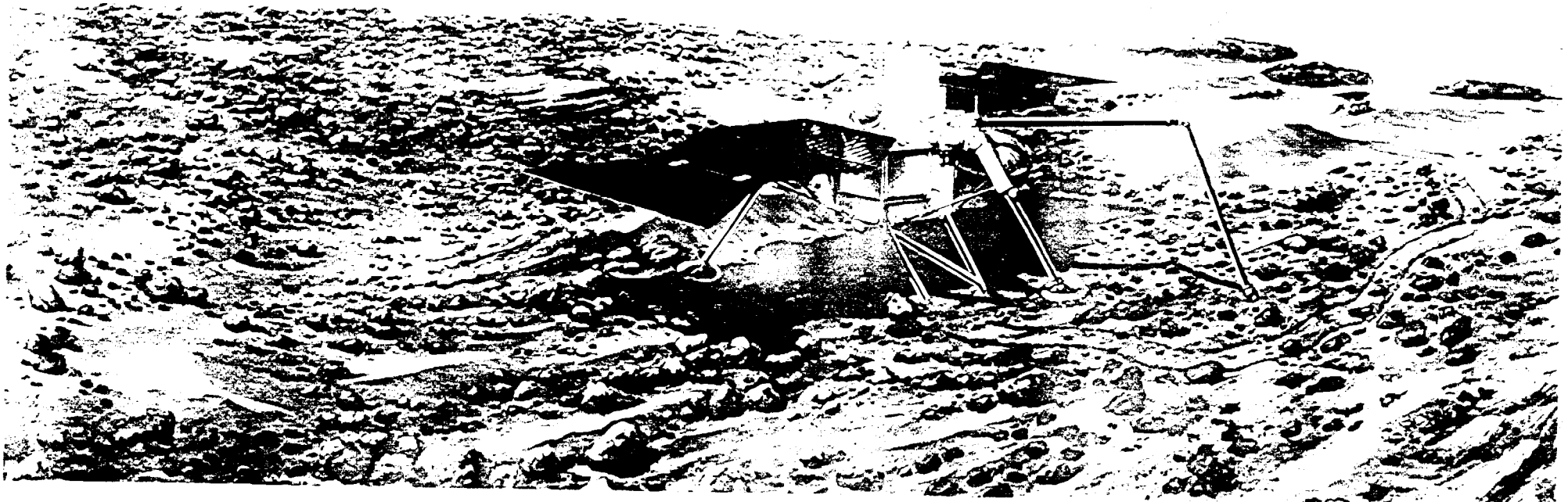




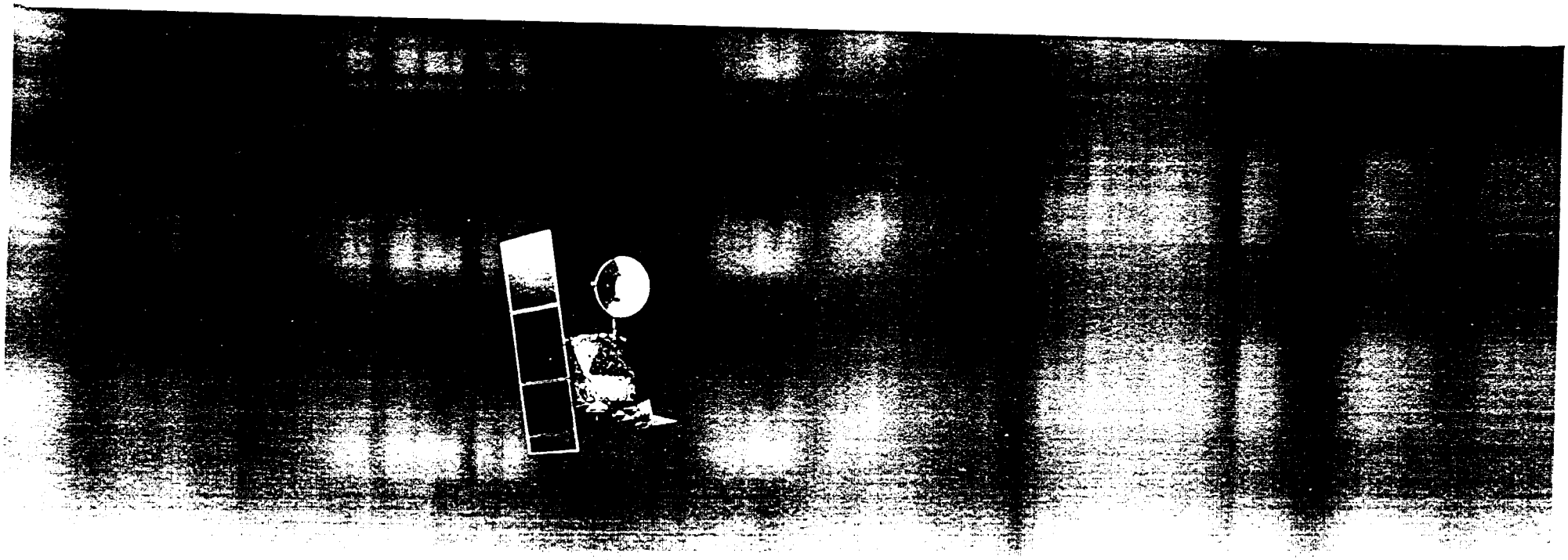
WL JLC

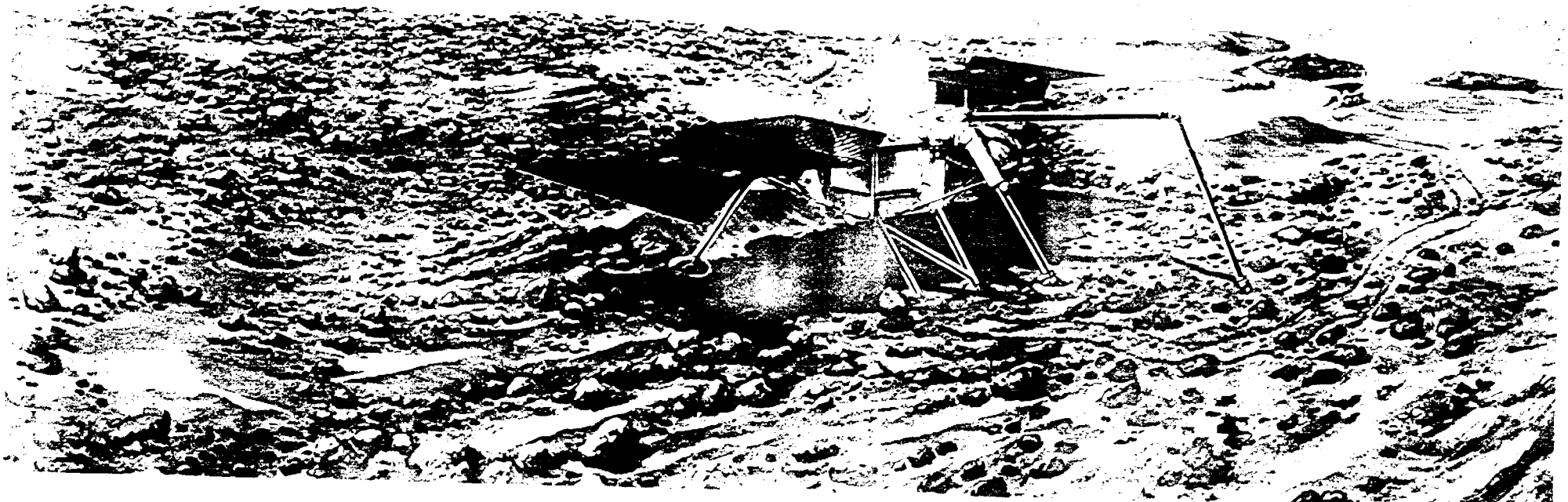
MARS '98





MARS
2001, 2003, 2005

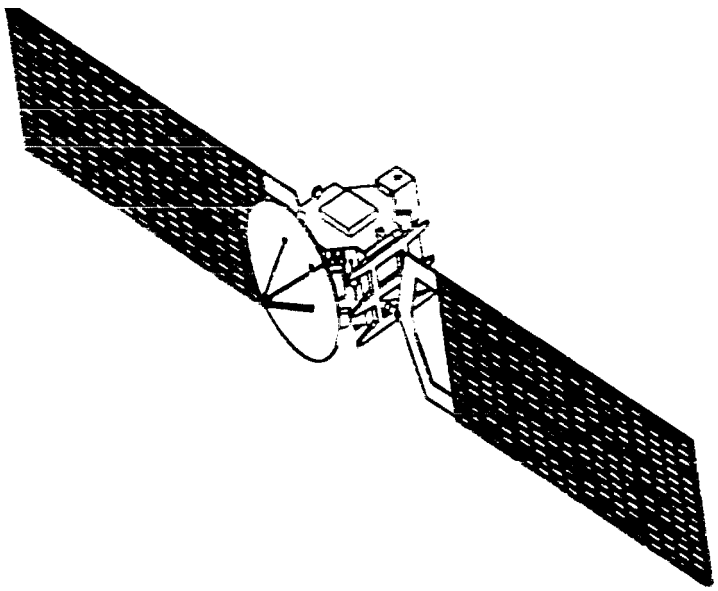




NEW MILLENIUM PROGRAM

DS-1: Asteroid and Comet Flyby

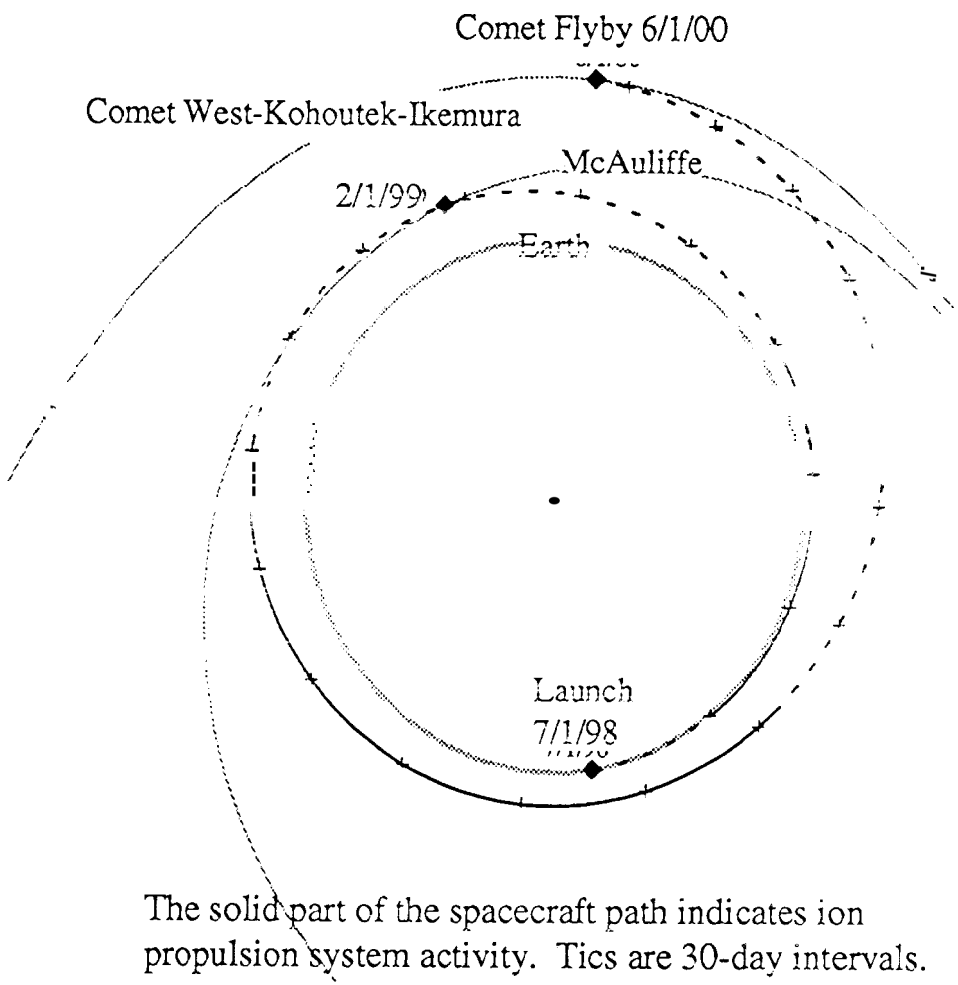
Enabling Fast Flexible Access to the Solar System



- Mission Highlights
  - Fly by 1 asteroid and 1 comet during primary mission
  - Trajectories developed for 2 asteroid/comet pairs
  - Industrial partner for mission definition and implementation is Spectrum Astro Inc., onboard October 1995
  - Spacecraft is 400 kg in launch configuration
  - Launch readiness date of January 1998; launch no later than July 1998
- Technology for Demonstration
  - Solar electric ion propulsion system
  - Miniature integrated camera and spectrometer (MICAS)
  - Autonomy - remote agent architecture
  - Autonomy - onboard optical navigation
  - 3D-stack processor
  - Ka-band solid state power amplifier

DS1: Baseline Mission Profile

McAuliffe/W K h tek-Ikemura Flyby



The solid part of the spacecraft path indicates ion propulsion system activity. Tics are 30-day intervals.

- Launch July 1998
  Reference date 7/1 98
- Encounter asteroid McAuliffe on 2/1/99
  - Flyby speed ~ 6.7 km/s
  - Earth range ~ 0.44 AU
  - Solar range ~ 1.19 AU
- Encounter Comet West-Kohoutek-Ikemura on 6/1 00
  - Flyby speed ~ 15.0 km/s
  - Earth range ~ 2.59 AU
  - Solar range ~ 1.60 AU

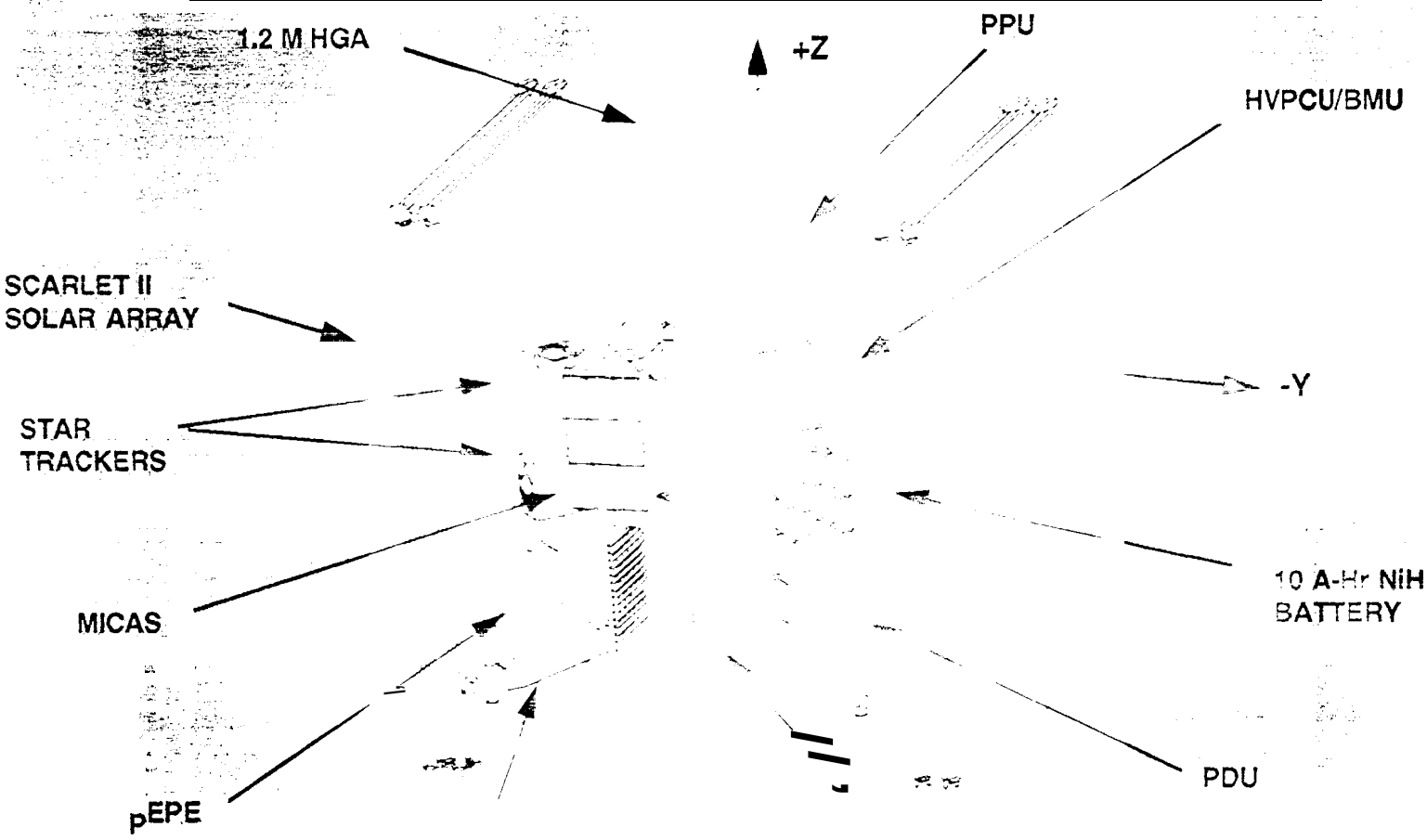
DS1 SPACECRAFT DESCRIPTION

- ⇒ ~ 350 kg Spacecraft
- ⇒ LMLV-2/Taurus Class Booster
- ⇒ 2600 W Power Generation
- ⇒ Xenon Ion Propulsion
- ⇒ Small Deep Space Transponder
- ⇒ Multispectral Imaging Camera & Spectrometer
- ⇒ Plasma Exp. for Planetary Exploration (PEPE)
- ⇒ 3D Electronics Stack w/ SSR
- ⇒ Full Onboard Autonomy
- ⇒ Optical Navigation
- ⇒ Multifunctional Structure
- ⇒ Ka-Band SSPA
- ⇒ Composite HGA
- ⇒ Beacon Mode Experiment

JPL

SPECTRUM ASTRO

DS1 EQUIPMENT ARRANGEMENT



15

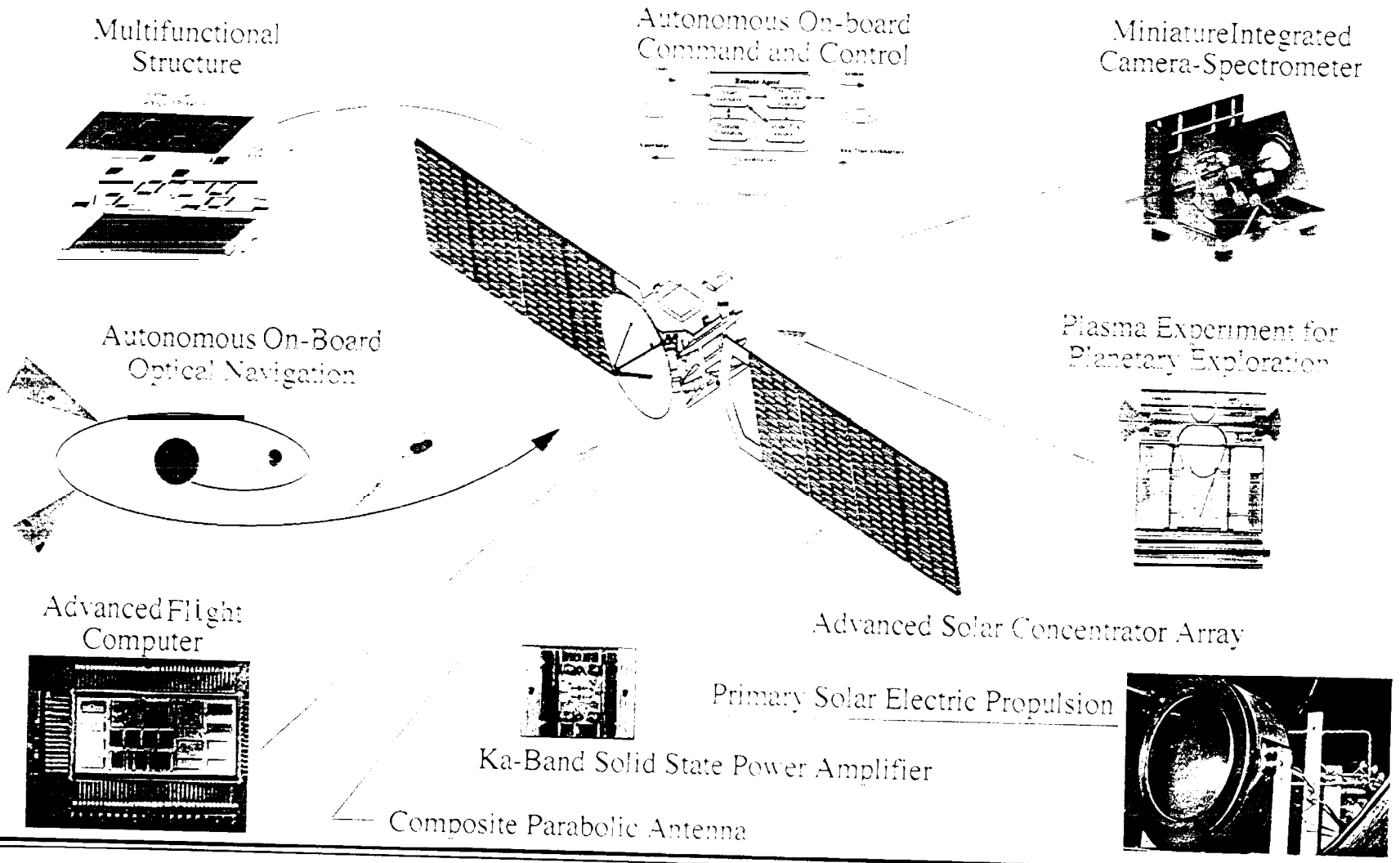
PROPULSION
MODULE

'EM
SLOT (17 EQUIV)
CARDCAGE

New Millennium Program

ASTEROID AND COMET FLYBY

DEEP SPACE ONE VALIDATION TECHNOLOGIES

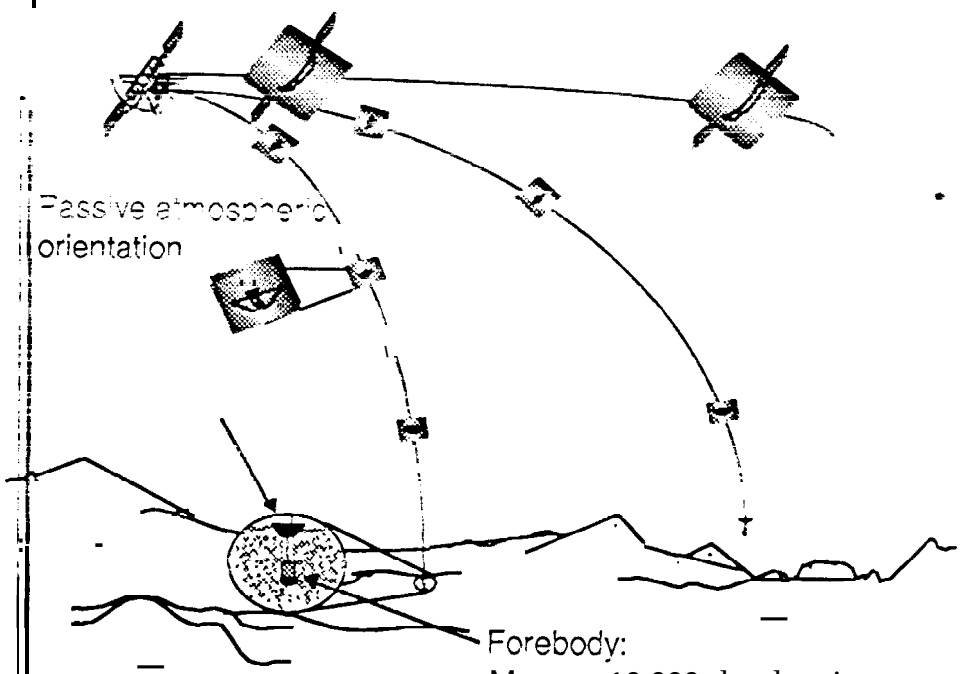


DS-2: Mars Microprobe

Enabling Future Network Science Missions

MARS MICROPROBE

ENTRY DESCENT AND LANDING

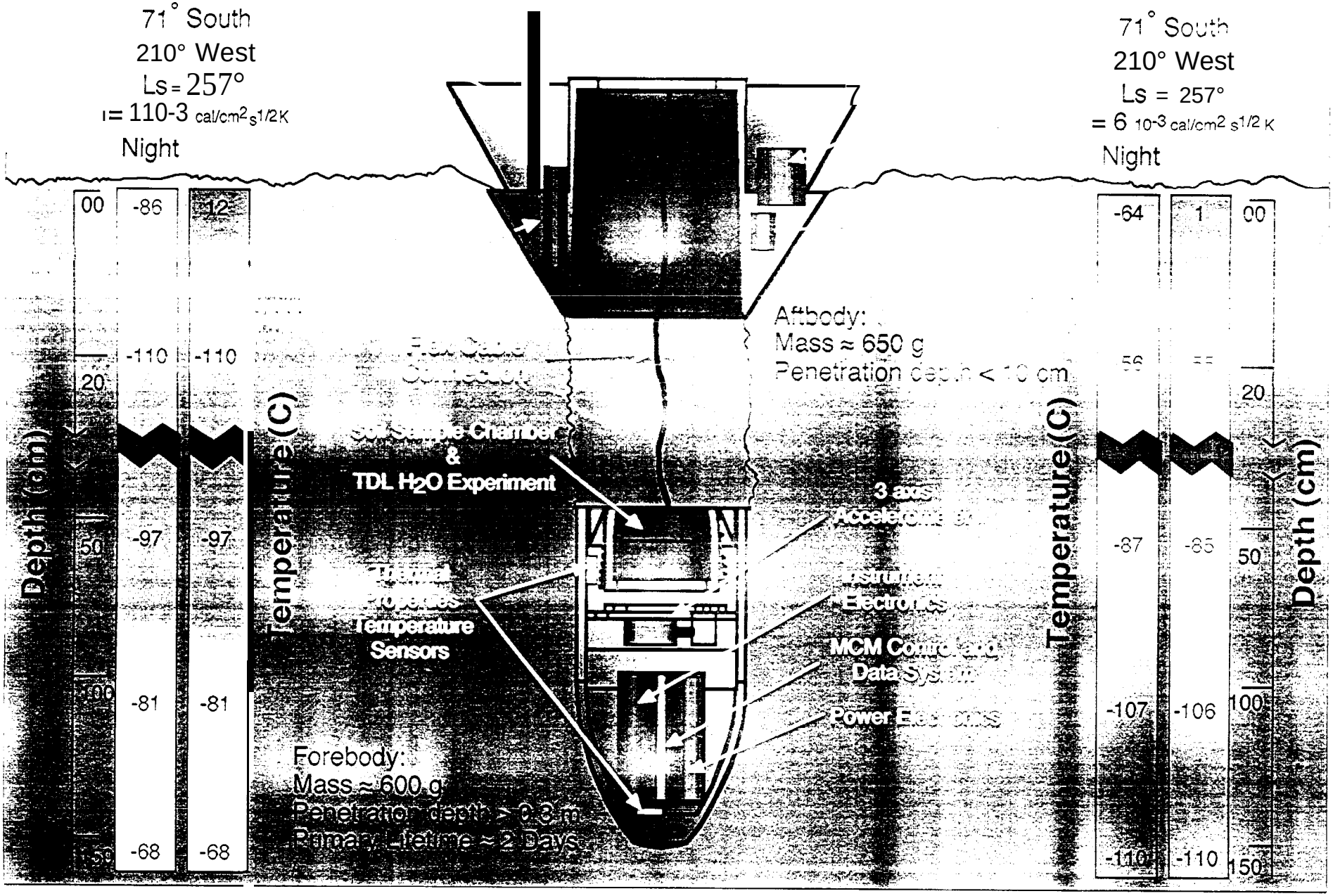


- Mission Highlights
  - 2 probes mounted on Mars 98 Lander Cruise Ring
  - Single-stage Mars entry, descent and landing
  - 1.3 kg micropenetrators
  - Highly integrated microelectronics designed to withstand both very low temperatures and high decelerations
- Technology for Demonstration
  - Non-ablative, single-stage-entry aeroshell
  - Microtelecommunications subsystem with programmable transceiver
  - Power microelectronics with mixed digital/analog ASIC
  - Ultra low temperature Li Ion Battery
  - Microcontroller with 3D HDI packaging
  - Flexible interconnects for system cabling
  - Meteorological high-g pressure sensor
  - Subsurface sampling/H2O detection experiment
  - Soil conductance high-g temperature sensor

G. Powell
3/1 3/96

JPL

(MARS OPERATIONS)



DISCOVERY MISSION

STARDUST

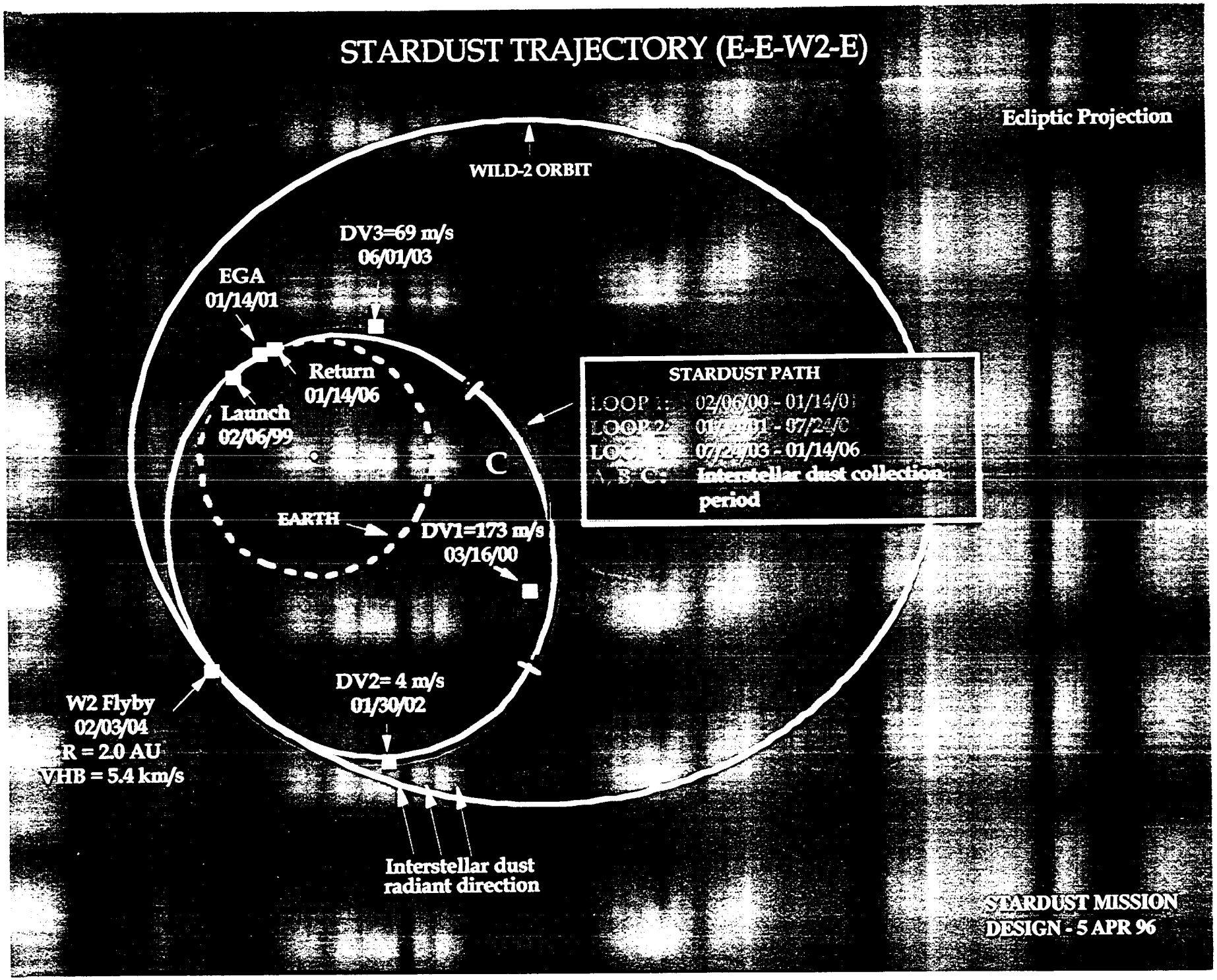
WOULD COME

THAT DESCRIBED MISSION

CONFIDENTIAL

4/25

KEN ATKINS ON TRAVEL
UNTIL 4/29. LEFT
MESSAGE W/ SECRETARY


STARDUST TRAJECTORY (E-E-W2-E)
Ecliptic Projection
WILD-2 ORBIT
DV3=69 m/s
06/01/03
EGA
01/14/01
Return
01/14/06
Launch
02/06/99
C
EARTH
DV1=173 m/s
03/16/00
DV2= 4 m/s
01/30/02
W2 Flyby
02/03/04
R = 2.0 AU
VHB = 5.4 km/s
Interstellar dust
radiant direction
STARDUST PATH
LOOP 1: 02/06/00 - 01/14/01
LOOP 2: 01/14/01 - 07/24/03
LOOP 3: 07/24/03 - 01/14/06
A, B, C: Interstellar dust collection period
STARDUST MISSION
DESIGN - 5 APR 96

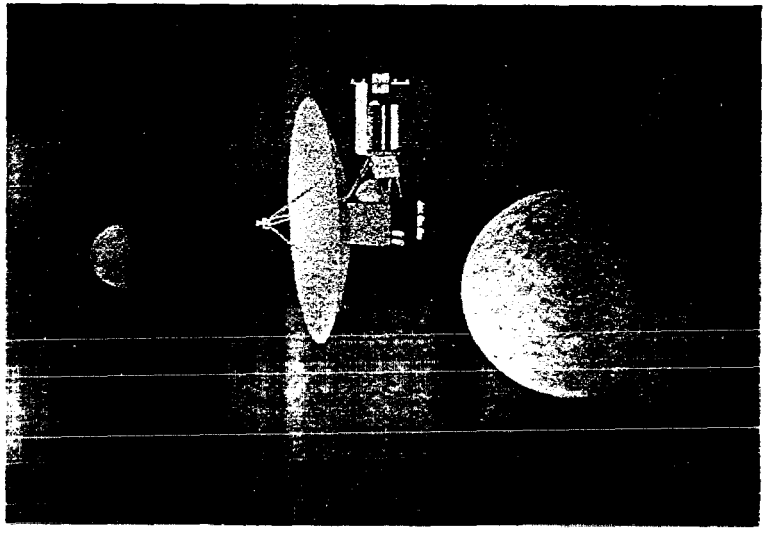
PLUTO EXPRESS

Pluto Express

... to Explore Pluto/Charon and open the Solar System to Low Cost Exploration

Mission Description

First Reconnaissance of the Pluto - Charon system
Dual small sciencecraft flyby of Pluto and Charon
Highly constrained life cycle and development cost
Extensive use of Advanced Technologies in reducing mass, power, operations complexity and cost



Primary Science Objectives

Characterize Global Geology and Morphology
Surface Composition Mapping
Characterize Neutral Atmosphere
-Structure and Composition

Status

Key subsystem and instrument protoype breadboards completed in 1993-1994
Launch targeted for 2001 +

For further information, please contact Robert L. Staehle, Pluto Preproject Manager, at (818) 354-1176.

Desire Concept

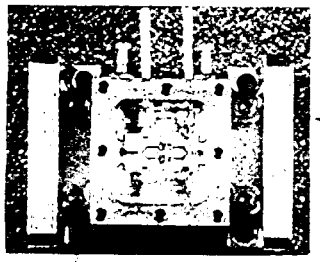
Launch Vehicle:	Delta II or Molniya*
Trajectory:	Multiple swingby
Flight Time:	1O-I3 years
Instruments:	Imaging, IR Mapping Spectrometer, UV Spectrometer, Radio Science Uplink Occultation, Atmospheric Drop Zond*
Sciencecraft Mass:	c100 kg Sciencecraft Module, < 640 kg total with propellant
Sciencecraft Power:	-80 Watts

• Proposed Elements for Russian cooperation

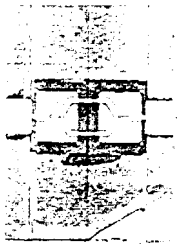
Pluto Technology improvement

Gas **Thrusters**

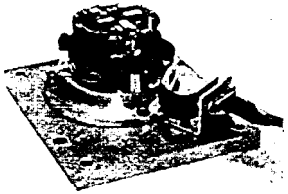
Service Valves



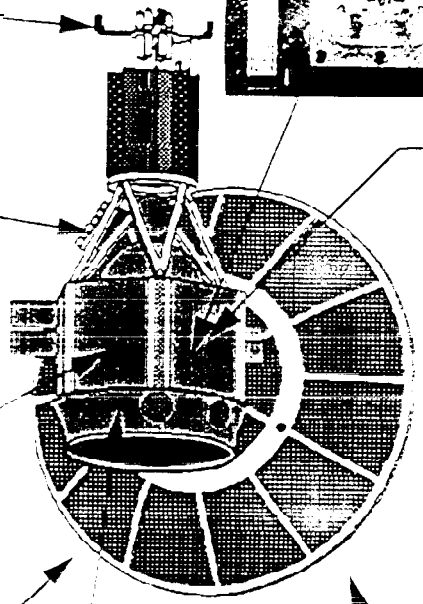
SSPA

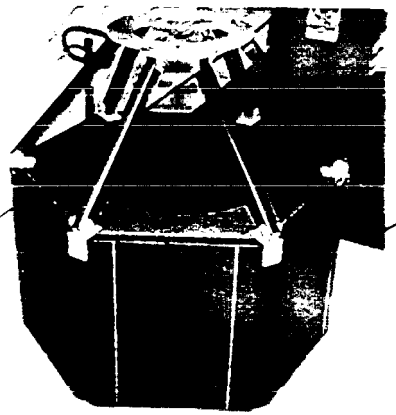


Micro Shield



IRUs

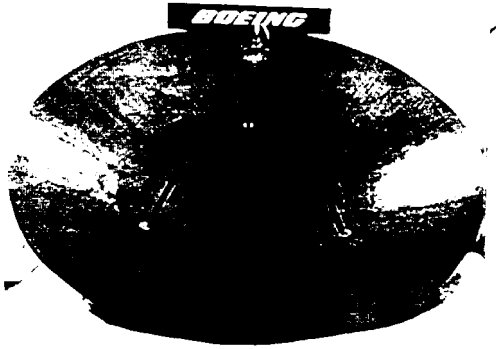




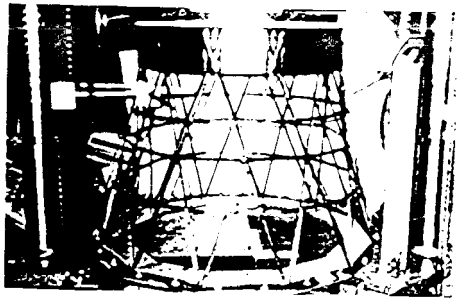
Composite Bus Structure

Miniaturized Pressure Regulator and Latch Valve
X-band Digital Receiver
Comp uter Module
Advanced RTG
SRV Stack Adapters
Prototype Isogrid Bus Structure
Micro Solid State Power Switch
Piezoelectric "Inchworm" Actuator
Strawman Instrument Prototypes
- Uplink Radio Science Instrument
- Ultrastable Oscillator
- Ultraviolet Spectrometer
- Integrated Pluto Payload System
- Instrument Package Miniaturization
- Linear Etalon Imaging Spectral Array
- Integrated UV/IR/Vis Instrument
- Instrument Data Interface
- 4-color CCD Mask Imager
- Reflective Imaging/Mapping Interferometric Sensor

Items Not Pictured



High Gain Antenna



Prototype Spacecraft Adapter

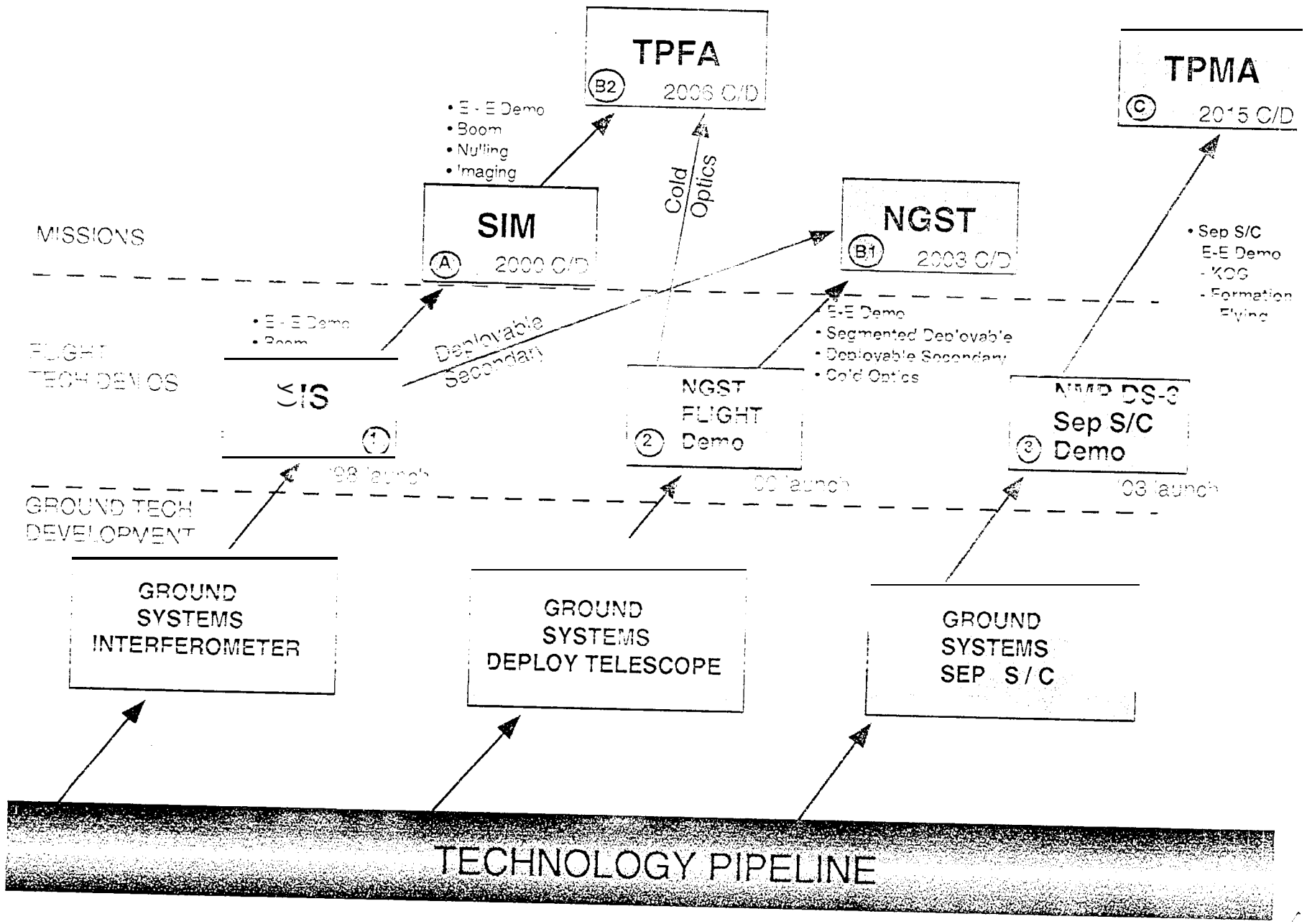
Visualization and Operations Software

SCB 940204

SCIENTIFIC THEME

ORIGINS

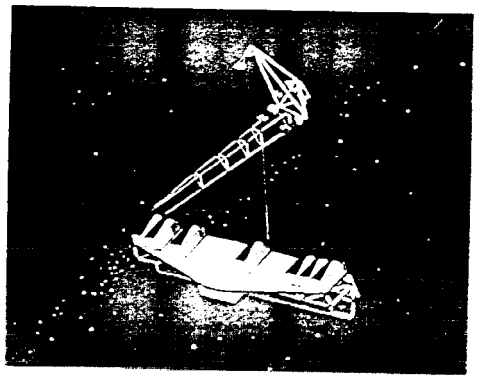
ORIGINS FLIGHT EXPERIMENTS - BASELINE THINKING



JPL

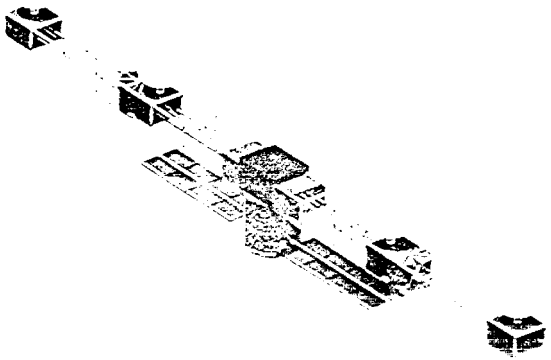
ORIGINS MISSION SET

SPACE INTERFEROMETRY MISSION (SIM)



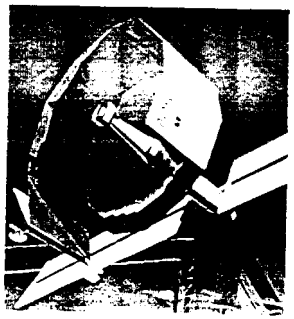
- ASTROPHYSICS AND PLANET DETECTION
- 7 - 20 METER BASELINE
- 0.3 - 2.0 MICRON WAVEBAND
- ASTROMETRY AND IMAGING

PLANET FINDER (PF)



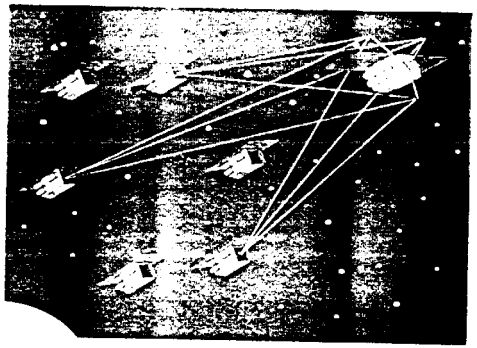
- PLANET DETECTION AND SPECTROSCOPY
- 50 - 100 METER BASELINE
- 2 - 20 MICRON WAVEBAND
- IMAGING AND SPECTROSCOPY

NEXT GENERATION SPACE TELESCOPE (NGST)



- **ASTROPHYSICS**
- **>4 METER FILLED APERTURE**
- **0.5-** 10 MICRON WAVEBAND
- IMAGING AND SPECTROSCOPY

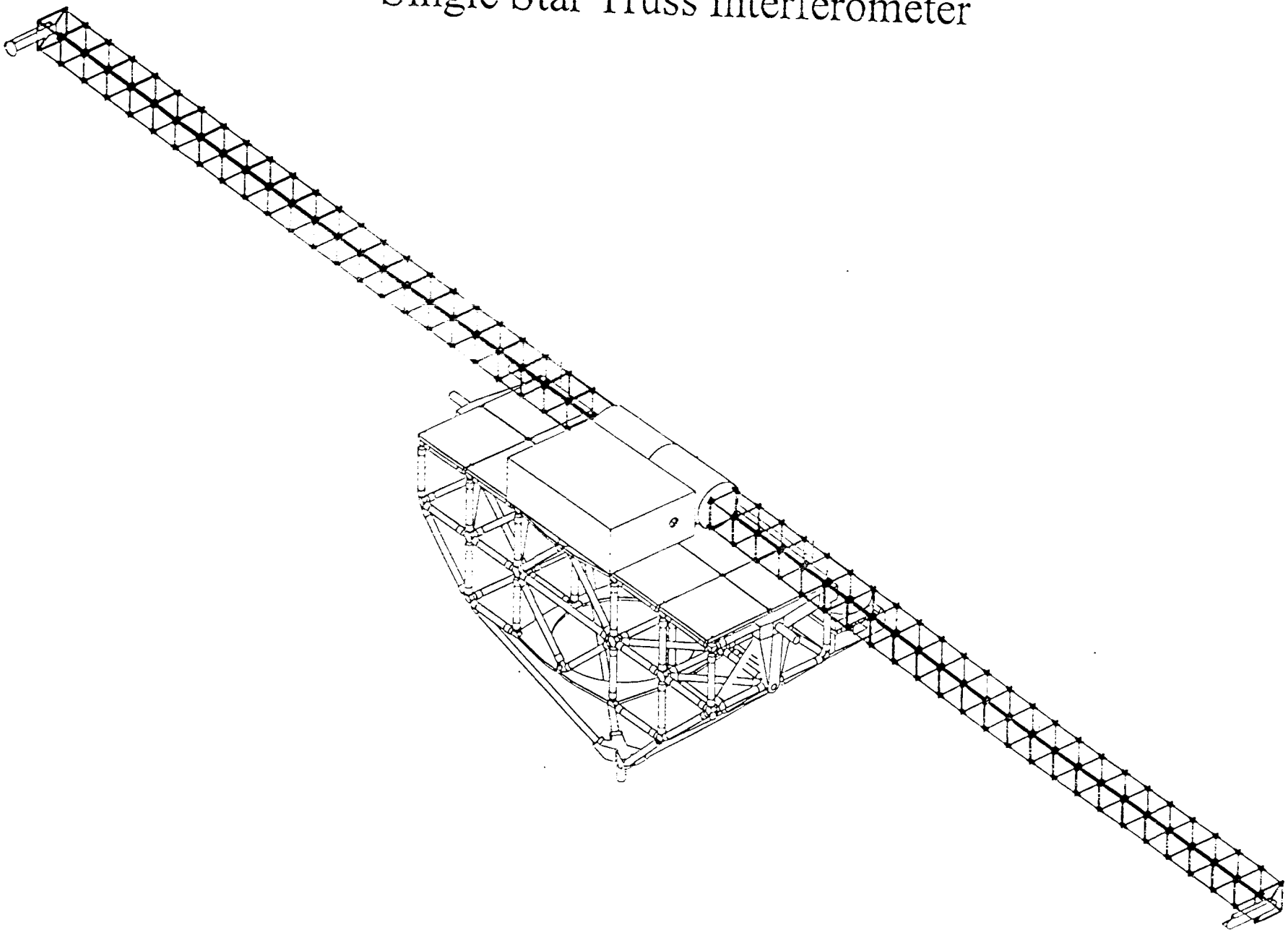
PLANET MAPPER (PM)



- ASTROPHYSICS AND PLANET IMAGING
- VIRTUALLY UNLIMITED BASELINE
- 0.5-20 MICRON WAVEBAND
- IMAGING AND SPECTROSCOPY

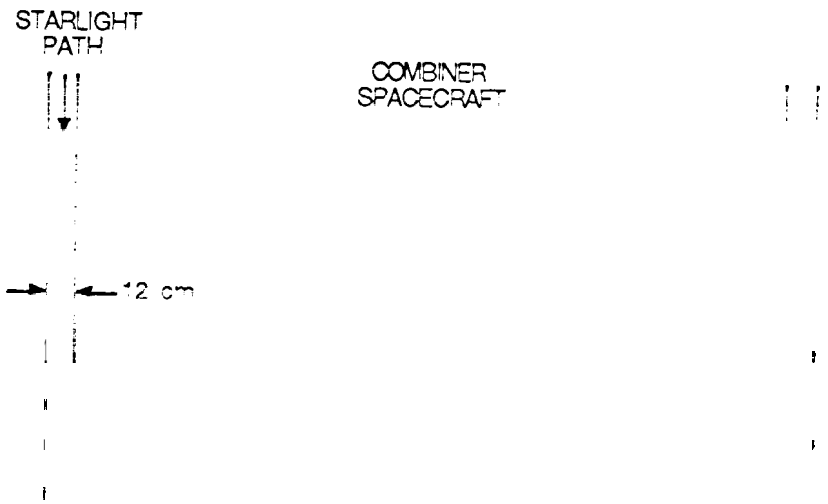
ISIS BASELINE

Single Star Truss Interferometer

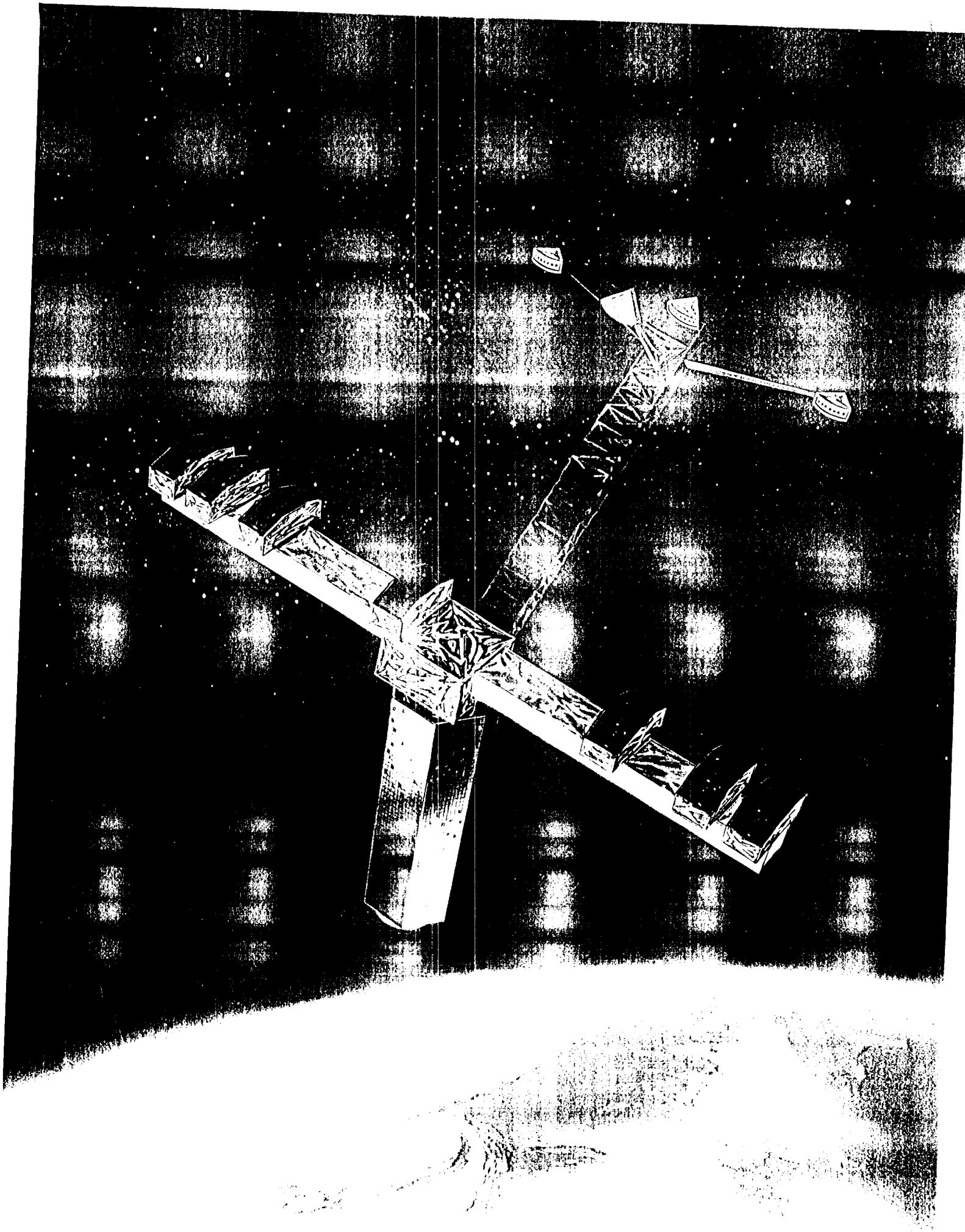


DS-3: Free-Flying Interferometer

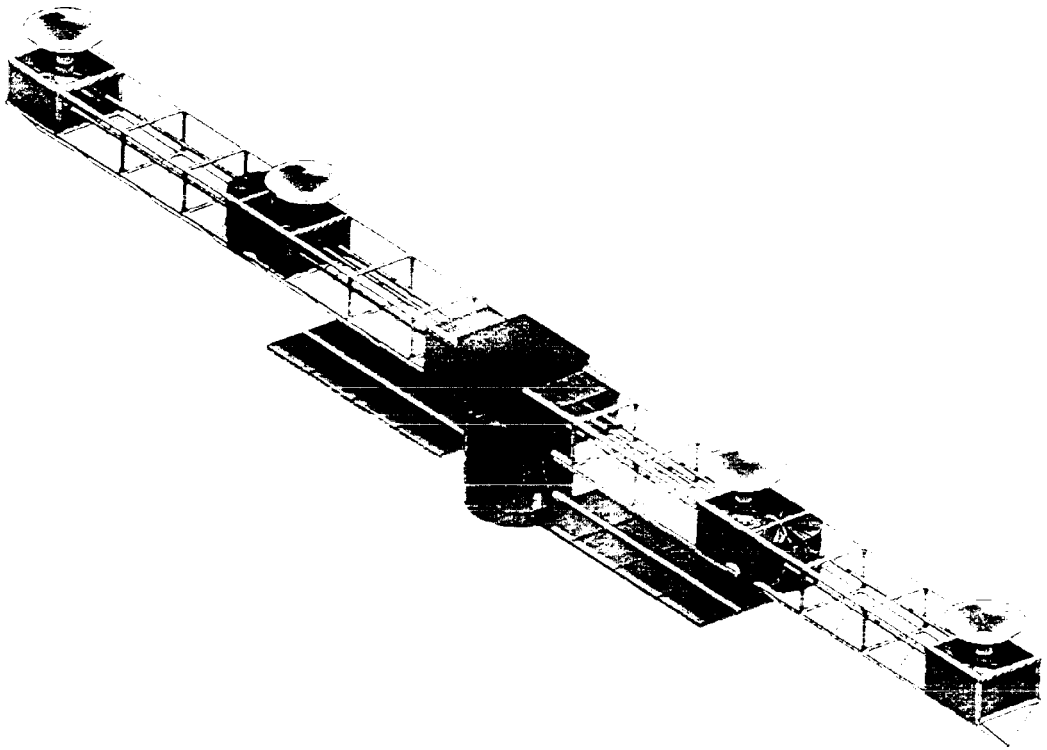
Enabling Detection of Extra Solar Planets



- Mission Highlights
  - Launch mid-2000
    One launch vehicle
  - SIRTF-like solar orbit
  - 6 month mission with full-sky access
  - Star detection down to 14th magnitude
  - ~150 kg wet for each of two collector spacecraft
    ~225 kg wet for combiner spacecraft
- Technology for Demonstration
    Three-spacecraft, cm-level formation flying
  - Kilometric optical gyro
  - Constellation initialization/control procedures
  - Nanometer-scale laser metrology
  - Miniature optical delay lines
    Miniature isolation/pointing system
  - High-resolution interferometry at km baselines



PLANET FINDER **(PF)**



- PLANET DETECTION AND SPECTROSCOPY
- 50-100 METER BASELINE
- 2-20 MICRON WAVEBAND
- IMAGING AND SPECTROSCOPY

NEXT GENERATION SPACE TELESCOPE

NGST Introduction: John Mather, Study Scientist, NASA GSFC

Technical requirement from Dressler committee; integral part of Origins program, shared technology and science with planet studies; study baby galaxies, star formation; ...

Study and construction budget and launcher guidance from Weiler, Kaplan; break HST cost paradigm!

GSFC, MSFC, STScI, JPL serious, resources committed, people assigned, office space, ... but this is not in house project

Baseline concept: 8m, 0.5-20 micron, L2, 10 yr, construct cost < $500 M

Atlas IIAS, 12' ID x 32' tapered fairing volume, ~ 6000 lb

Titan IV/SRM/Centaur gets 6000 lb to 1 x 3 AU orbit, costs 2.5 x as much

Technology demonstration needed - flight?

Report on feasibility for presentation to decadal survey, etc. by late 97

Scientific goals

Cosmology: high z supernovas, evolution of structure. dark matter, distance scales, photometric redshifts

Galaxy formation: first starlight, pieces assembling. change of morphology, interactions. consumption and enrichment of IGM

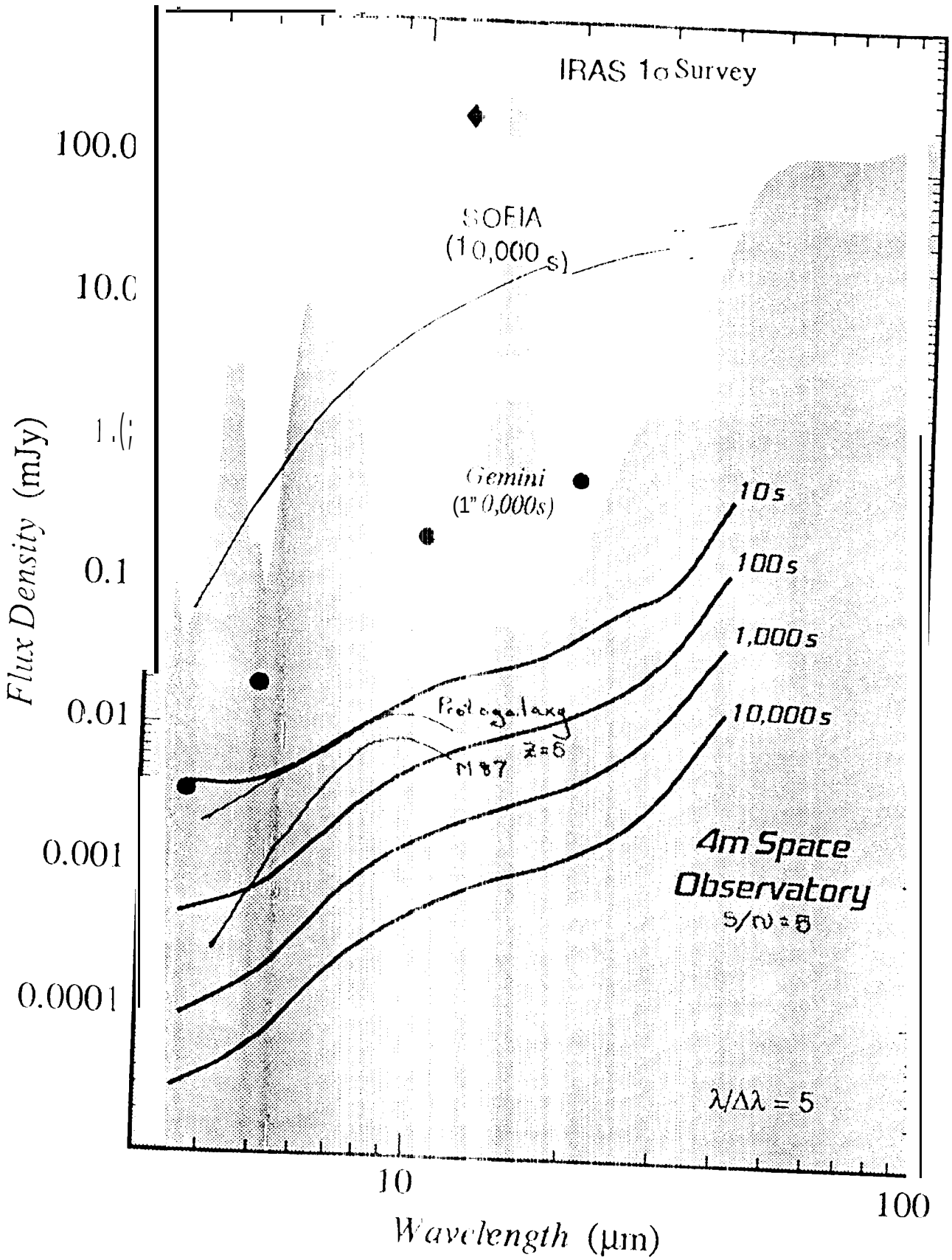
Closer to home: star and planet forming regions, see through dust clouds, map dust disks around stars, help find planets

3 ways unique:

wide field diffraction limited resolution at visible (bigger HST; cf laser guide star, active optics on ground for < 2 microns)

high sensitivity high resolution at > 2 micron: 1 ttle grou nd sensitivity past 2 microns

10x aperture of next largest cold telescope, SIRTF



Atmospheric Optical Depth at Manua Kea

TELESCOPE SCIENTIFIC DRIVERS

REQUIREMENT	IMPACT
1-5 MICRONS ZODI-LIMITED IMAGING	T < 70 K; HIGH ORBIT OR L2 POINT WITHIN 70 DEG OF SUN
SENSITIVITY 1.4 nJy (10 SIGMA) IN 10000 SECONDS	12 SQUARE METERS AREA MORE IS BETTER!
FIND SUPERNOVAE	LARGE FOV, > 3 x 3 ARCMIN
HST ANGULAR RESOLUTION	4 - 8 METER APERTURE, 0.06 - 0.1" FWHM
5-20 MICRONS COVERAGE	COLDER TELESCOPE, INSTRUMENTS (40K)
VISIBLE COVERAGE	COLD DETECTORS FOR VISIBLE
ALL-SKY POINTING ONCE/YR	LARGE SUNSHIELD LINE OF SIGHT PERPENDICULAR TO SUN
SUPERNOVA MONITORING	WIDE SKY COVERAGE (>20%)

Reasons for Optimism

Good location at L2 - "easy" system design

New materials - much better than old; composites and SiC

Mechanical design and manufacturing tools much better than old

Adjustment technology - wavefront sensors, piezos, screws available

Benefits of military investments

Commercial revenue supports new tech: PC manufacturers need amazing optical and mechanical things - perfect optics for photo-lith; perfect positioners for disk drives; etc.

New procurement strategy: "performance based contracting",provides high motivation, may allow more collegial relations; permit prime contractor, possibly excepting instruments (not in house project)

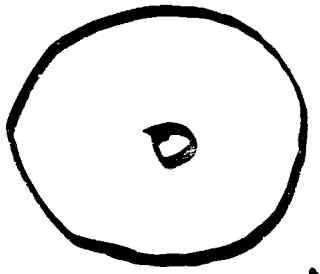
Technology demonstration reduces schedule, budget risk

Community enthusiasm: astronomers, commercial, DoD, Europe, Japan, to top NASA management including Goldin

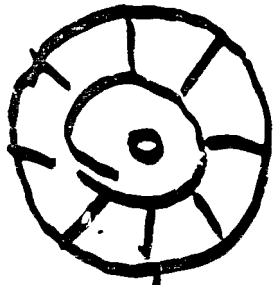
Conclusion: tough challenge, believe it's possible

MIRROR

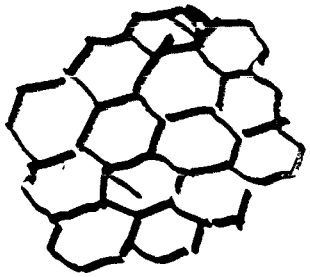
Ritchey-Chretien
with re-imaging + stops



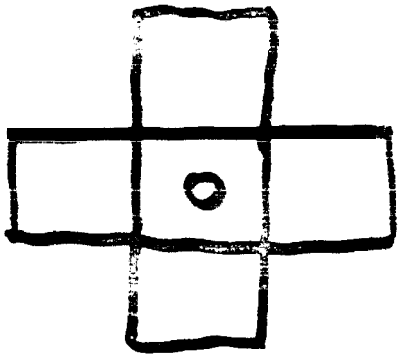
monolithic



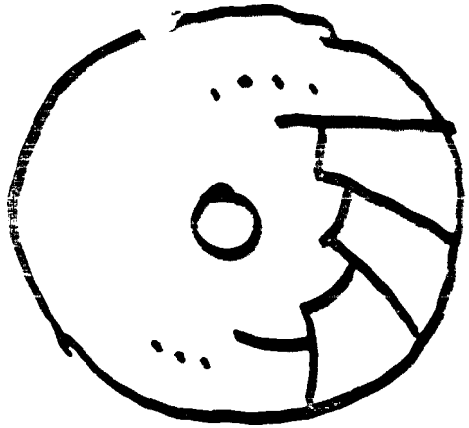
center + petals
(fold fwd, back)



"Keck"



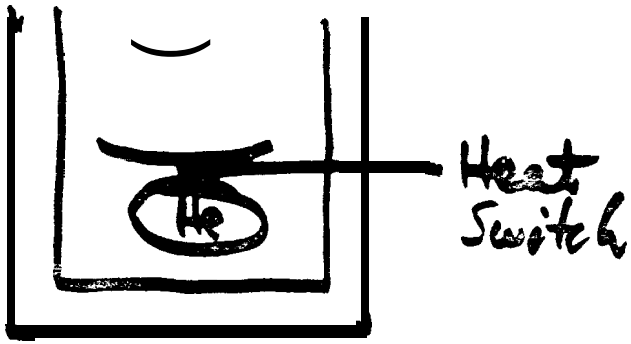
Stubby Mills Cross



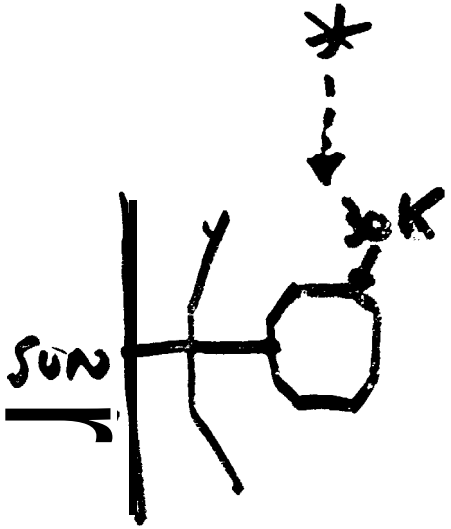
Vegetable Steamer

COOLING

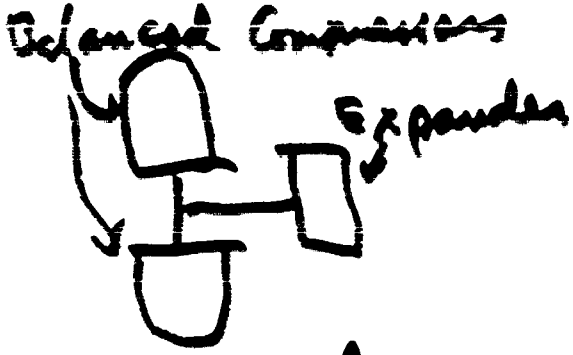
COBE



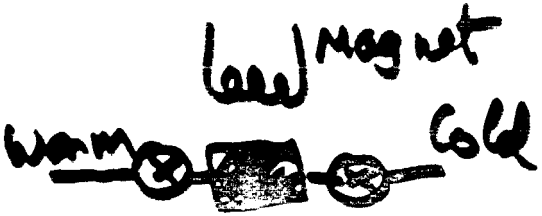
WARM LAUNCH SIRTF



DESIRE

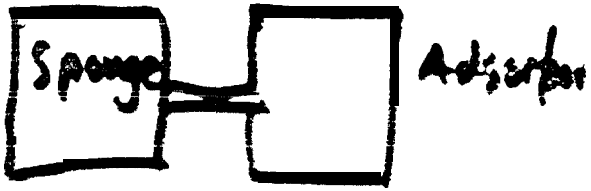


Mechanical Cooler

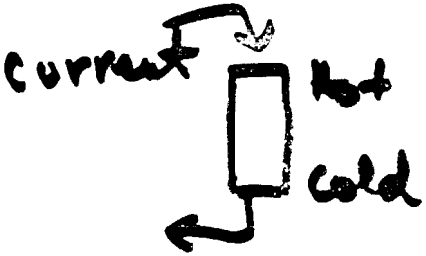


Adiabatic Demag.

SORPTION



Use ^3He, ^4He, H_2, Ne, N_2, O_2, ...

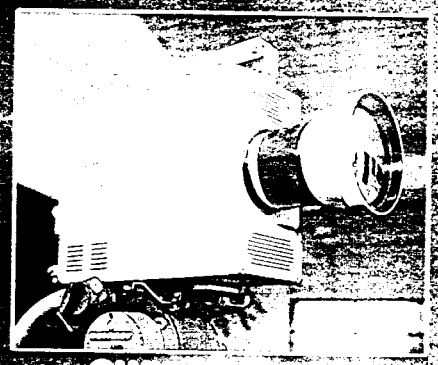


Thermoelectric - Peltier, S/C.

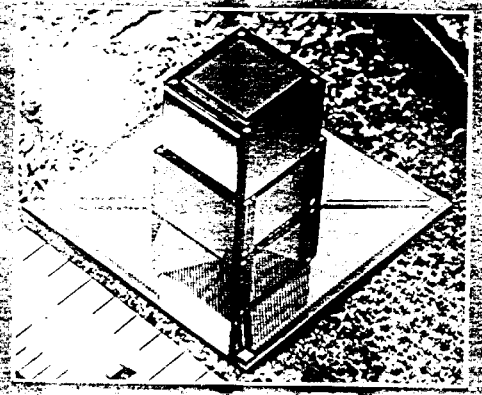
TECHNOLOGY FLIGHT EXPERIMENTS

JPL 2000 Technology Aircraft Flight Demonstrations

AIRBORNE VISUAL IR INSTRUMENT



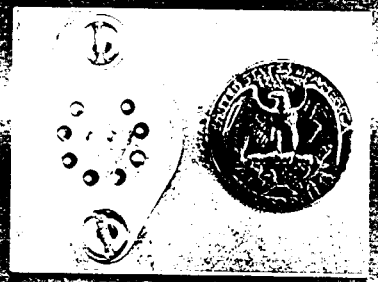
QWIP



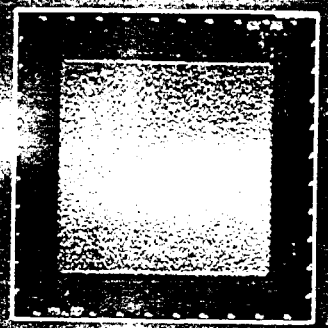
PLANET PROCESSOR

ACTIVE PIXEL SENSOR

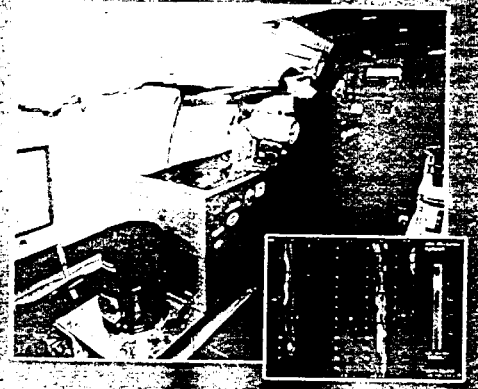
GEOSAR



HYGROMETER

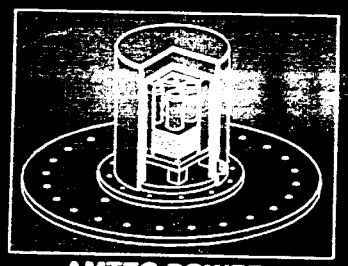


DEEP DEPLETED CCD



AIRBORNE EMISSION SPECTROMETER

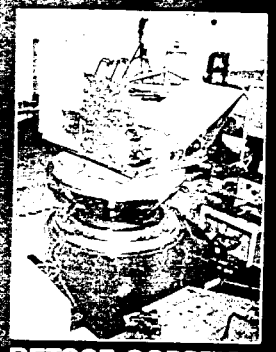
JPL 2000 Technology Space Flight Demonstrations



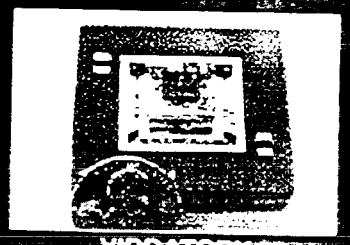
AMTEC POWER CONVERTER

SOJOURNER

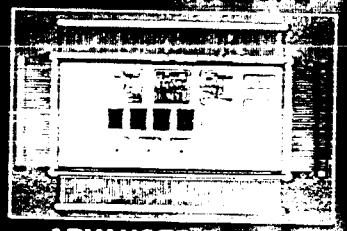
CRYO COOLER EXPERIMENT



BETSCE SORPTION COOLER EXPERIMENT

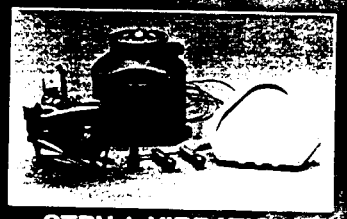


VIBRATORY MICROGYROSCOPE

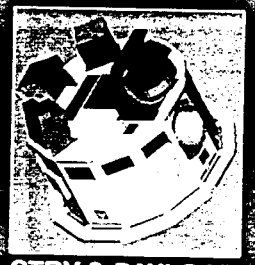


ADVANCED FLIGHT COMPUTER

MICROSEISMOMETER

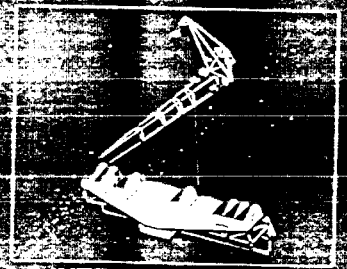


STRV-1 VIBRATION SUPPRESSION



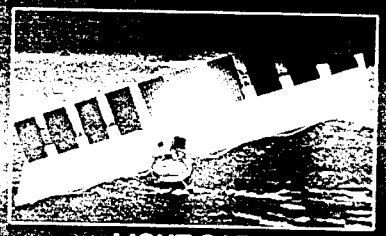
STRV-2 PAYLOAD MODULE

N-STAR ION THRUSTER



INTERFEROMETRY

INFLATABLE ANTENNA EXPERIMENT



LIGHT SAR