NEW MILLENNIUM PROGRAM

IPDT FORUM

FUTURE MISSIONS

JANUARY 28, 1997

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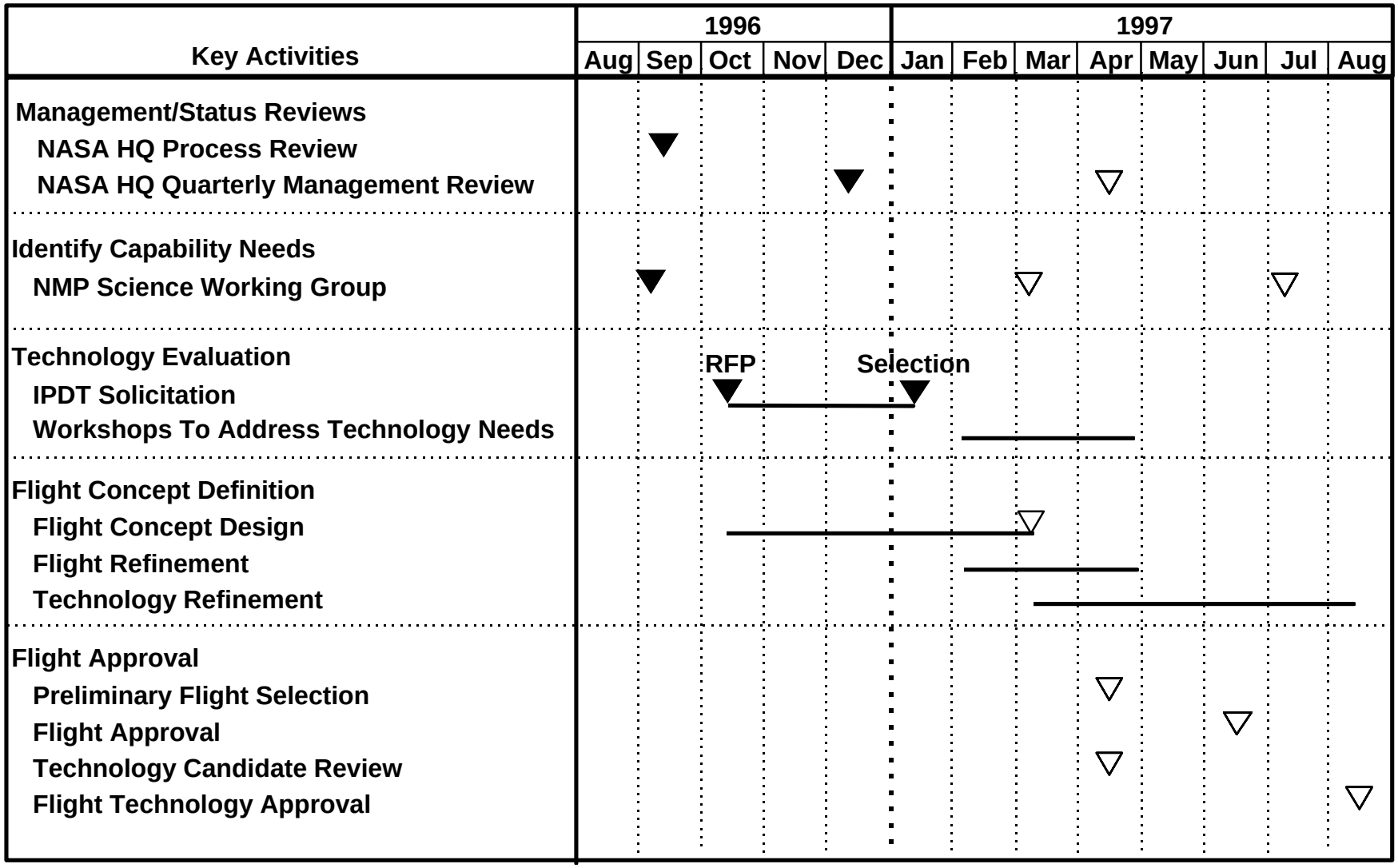
ARCHITECTURE DEVELOPMENT TEAM

NMP SCHEDULE OF KEY ACTIVITIES



ADT ACTIVITIES

- **MISSION CONCEPT DEFINITION FOR DEEP-SPACE (DS) AND EARTH ORBITING (EO) MISSIONS**
  - Seeking NASA (Code S) approval for DS3 and DS4. Investigating candidates for DS5.
  - Seeking NASA (Code Y) approval for EO2.

- **ADT RESPONSIBILITIES**
  - **DEFINE OVERALL MISSION ARCHITECTURE**
    - Mission design
    - Spacecraft / payload concepts
    - Mission operations
  - **IPDT / SCIENCE INTERACTION**
    - Define / refine instrument system concepts
    - Work with IPDTs to identify other technology candidates for flight validation
  - **DEFINE PRELIMINARY IMPLEMENTATION FEATURES**
    - Schedule / Cost
  - **MISSION APPROVAL**
    - Continue to refine mission concepts throughout the mission approval process

TOP LEVEL GUIDELINES FOR FUTURE DEEP SPACE VALIDATION FLIGHTS

DS3 Validate the technologies for multi-spacecraft formation flying optical interferometry. Options to be explored should include but not be limited to:

- Late 2000 or 2001 launch
- Cost range between $60M to $80M excluding launch vehicle
- International cooperation with DLR in which DLR provides the 2 collector spacecraft

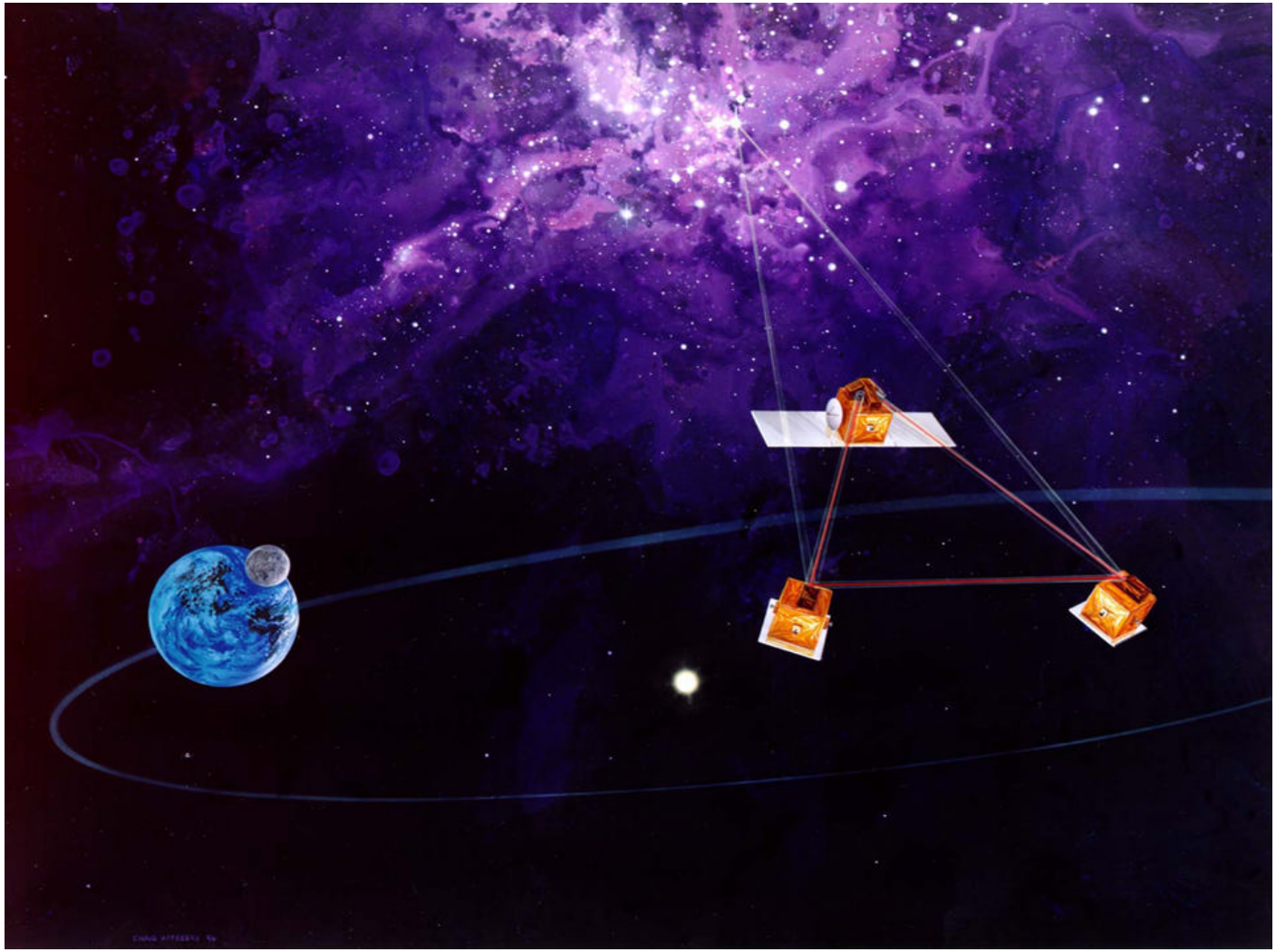
DS4 Validate the technologies for small body sample acquisition and sample return. Options to be explored should include but not be limited to:

- 2003 launch
- Cost range between $60M to $80M excluding launch vehicle
- Collaboration with the Champollion Project in order to deliver the Champollion lander to a comet

DS5 Validate at the system level enabling technologies for the 21st century in a piggyback mission (similar to DS2). Options to be explored should include but not be limited to:

- 2004 launch
- Cost range between $20M to $35M
- Venus or Mars aerobot
- Microrover for an asteroid
- Solar sail spacecraft
- Inflatable optical mirror demo

DS3
MULTI-S/C OPTICAL INTERFEROMETER



DS3 MISSION CONCEPT DEFINITION

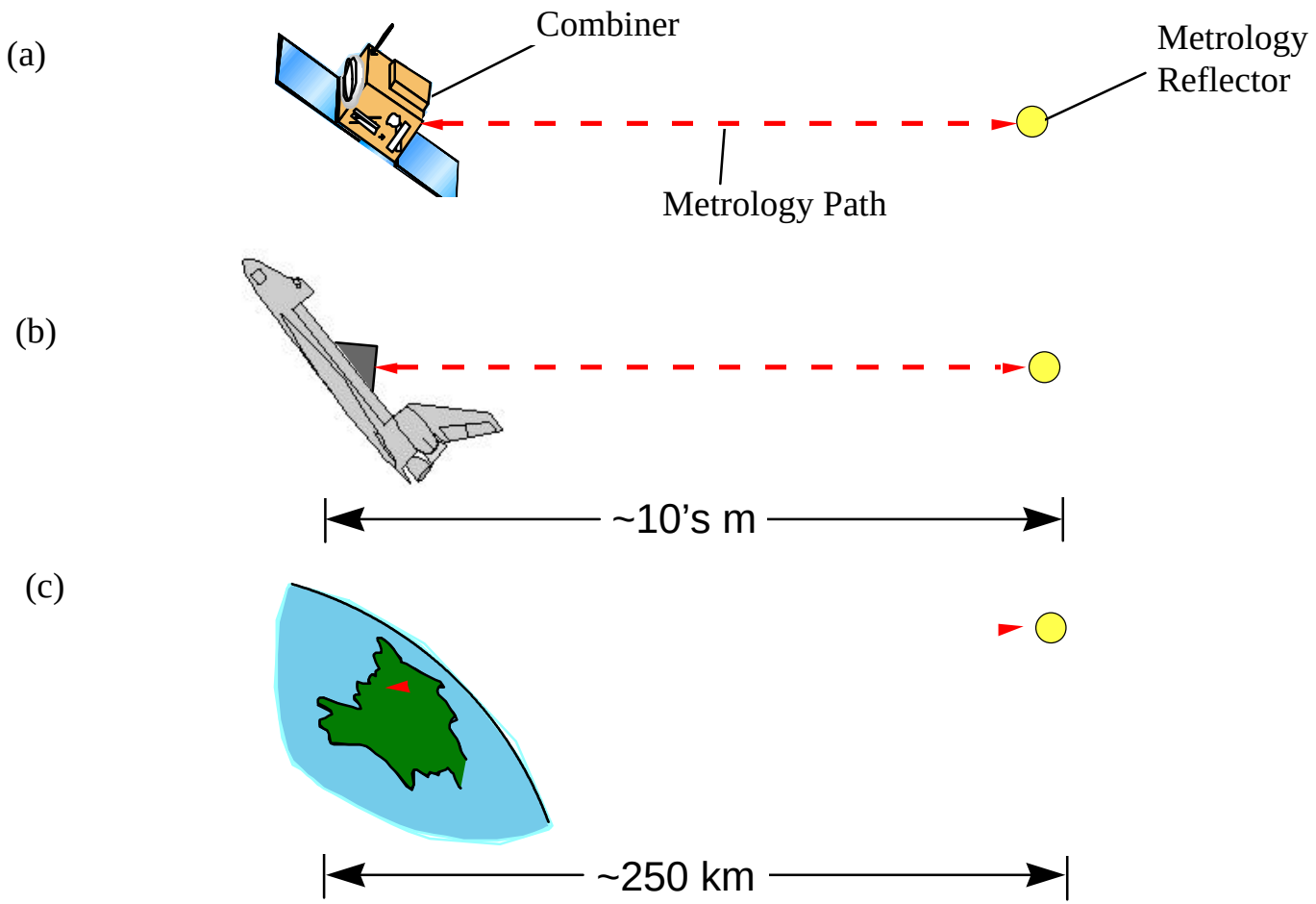
- **KEY OBJECTIVES**
  - To demonstrate the technology to enable future multi-spacecraft (or separated spacecraft) interferometers for astrophysics and extrasolar planet detection.
  - To demonstrate formation flying technology to enable other types of future missions involving multiple spacecraft and instruments.
- **GENERAL MISSION CHARACTERISTICS**
  - Trajectory: A heliocentric solar orbit (SIRTF-type Earth escape trajectory) with a maximum distance of ~0.1 AU from the Earth after 6 months.
  - Launch Vehicle: Med-Lite class. Single launch for all spacecraft.
  - Launch Date: Late 2000 / 2001
  - Mission Duration: Minimum 6 months
- **DS3 DESIGN TEAM**
  - DS3 ADT Study Lead is Ken Lau.
  - The ADT is working with members of the JPL Interferometry Center of Excellence (ICE).
- **CONFIGURATION OPTIONS**
  - The DS3 Design Team is currently evaluating several different configurations.
    - Cost vs science capability vs technology trades
    - Configurations range from no science to significant science capability
      - 1, 2, and 3 spacecraft options are being considered

DS3 TECHNOLOGIES vs CONFIGURATION OPTIONS

Technologies & Capabilities	Flight Configurations															
	1	2	3	4	5	6	7		8	9						
LASER METROLOGY & CONTROL																
Acquisition	★	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Measurement		★		•	•	•	•	•	•	•	•	•	•	•	•	•
				★	•	•	•	•	•	•	•	•	•	•	•	•
FORMATION FLYING																
			★	•	•	•	•	•		•	•	•	•	•	•	•
Medium Control (<1 cm, < 1 arcmin relative)					★	•	•	•		•	•	•	•	•	•	•
Precision Control (<1 micron, ~<0.1 arcmin relative)						★		•								
Formation Maneuvers							★	•			•	•	•	•	•	•
STARLIGHT FRINGES																
Single Baseline									★	•	•	•	•	•	•	•
1-D Aperture Synthesis												★	•	•	•	•
2-D Aperture Synthesis											★			•	•	•
										★	•					
												★	•	•	•	•
Fringe Acquisition at Long Baseline													★	•	•	•
FAINT OBJECT CAPABILITY																
															★	
Kilometric Optical Gyro																★

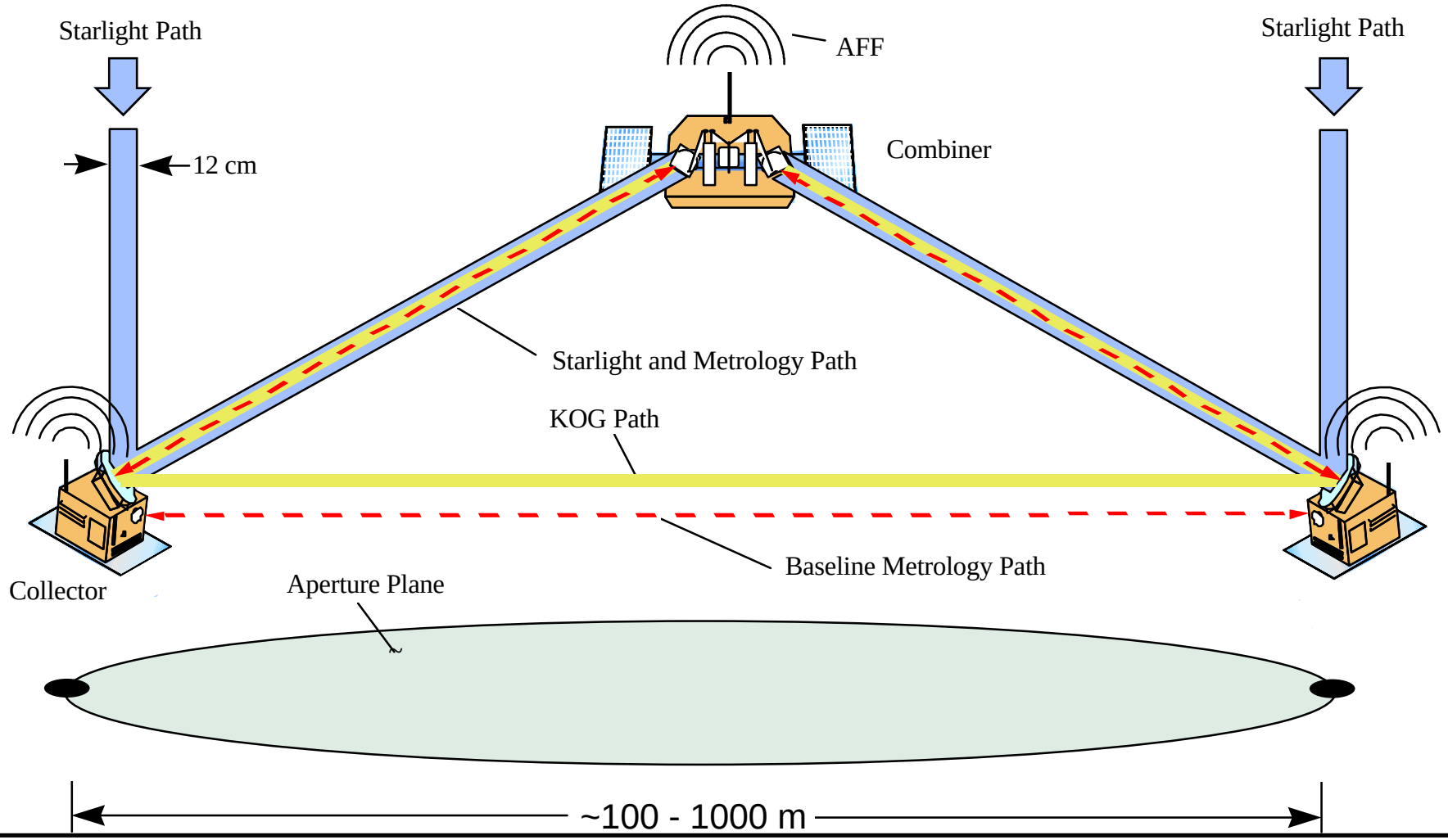
DS3 - CONFIGURATION 1

- Laser acquisition: return from a second (micro) spacecraft
- No formation flying control

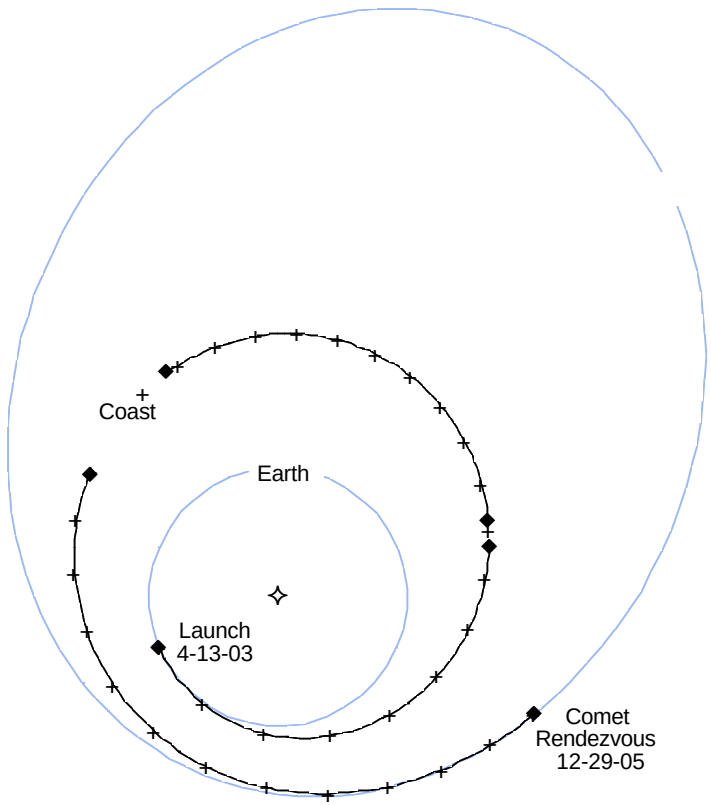


DS3 - CONFIGURATION 15

- 3 spacecraft Formation Flying with 2-D aperture synthesis
- 100-1000 m baseline
- Faint object capability: Kilometric Optical Gyro (KOG)



DS4
SMALL BODY SAMPLE ACQUISITION TECHNOLOGY DEMONSTRATION



Candidate DS4 Mission

- Comet rendezvous using SEP
- Target body: Tempel I
- Flight time: 2.7 years
- 30 day time tics on spacecraft path

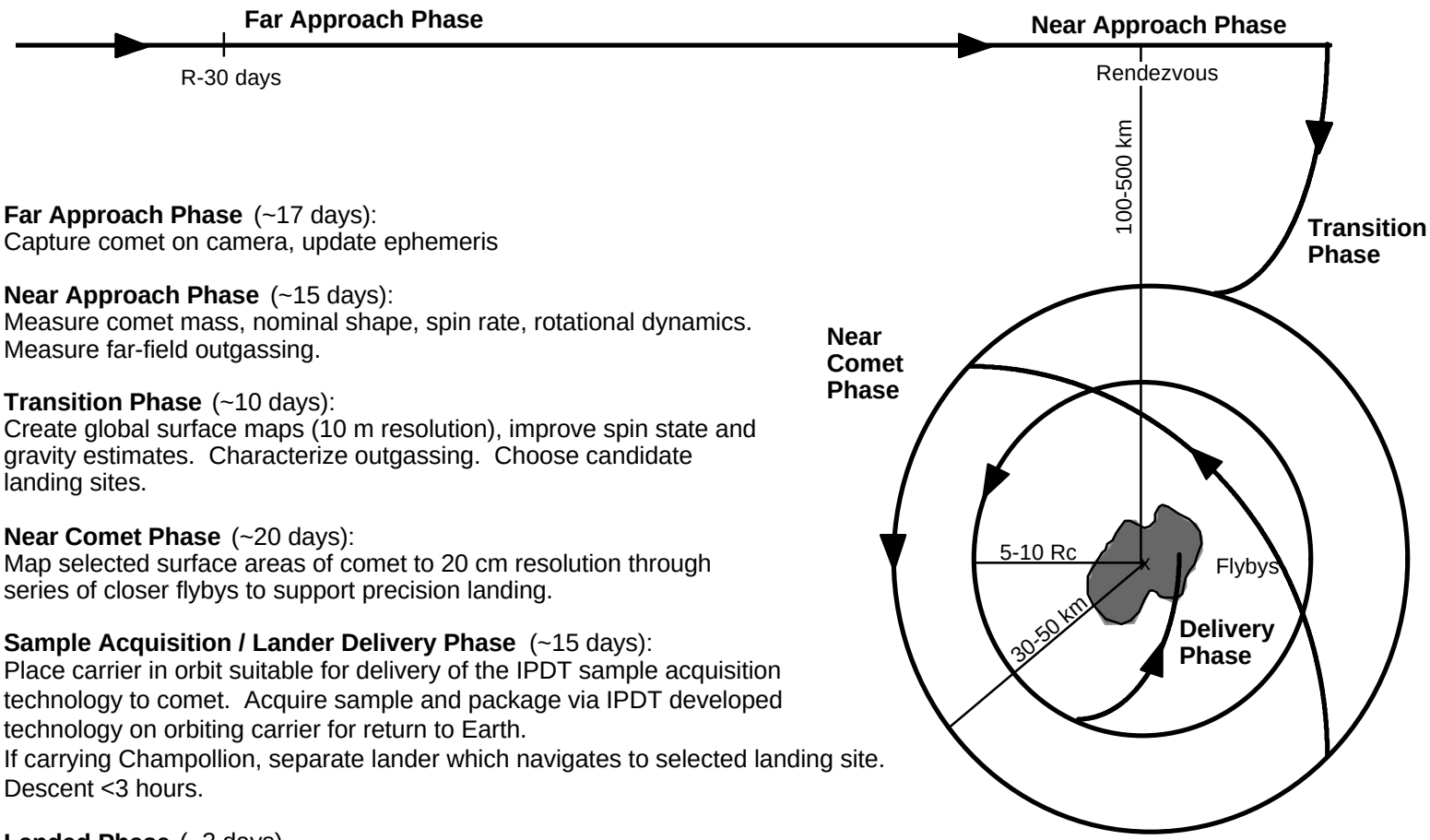
DS4 MISSION CONCEPT DEFINITION

- **KEY OBJECTIVES**
  - To demonstrate the ability to rendezvous with a small body, map the surface of the body, identify possible landing sites, deliver one (or more) vehicles or devices to the surface of the body to collect a sample, retrieve the collected sample(s), and package the sample(s) for return to the Earth. It is desired, but not required, that the sample actually be returned to the Earth.
  - For the Champollion option: To deliver the Champollion lander to a scientifically interesting comet and ensure the acquisition of the lander science data.
- **MISSION TARGET OPTIONS**
  - Short period comet
    - Good opportunities to Tempel I in 2002 and 2003 using Solar Electric Propulsion (SEP). Arrival in late 2005 / early 2006.
  - Near-Earth asteroid or Phobos / Deimos
    - Several opportunities in 2002 and 2003 for small spacecraft using chemical propulsion. Arrivals in 2003 through 2007. Deimos is the easiest for rendezvous with 2003 launch.
- **GENERAL MISSION CHARACTERISTICS**
  - Launch Vehicle: Med-Lite class. (For full-up sample return, Delta II 7925 is allowed).
  - Launch Date: 2003
  - Tempel I Option: Cruise phase 2.7 years, comet operations approximately 3 months.
- **DS4 DESIGN TEAM**
  - DS4 ADT Study Lead is Ted Sweetser.
  - For the Champollion option, the ADT is working with members of the Champollion Project.

DS4 MISSION STRATEGY OPTIONS

- **ENHANCED CHAMPOLLION LANDER TO TEMPEL I IN 2003**
  - This option is based on developing a lander and a cruise stage as a single, highly integrated spacecraft (minimizing the duplication of subsystems). An enhanced, smart Champollion lander would be the core of the spacecraft, with the cruise stage portion carrying the propulsion, power, and telecom subsystems.
- **HIGH-RELIABILITY CARRIER WITH CHAMPOLLION LANDER TO TEMPEL 1 IN 2003**
  - High reliability carrier developed by NMP using state-of-the-art technologies (but including minimal or no high-risk technologies) to ensure acquisition of the Champollion lander science data. NMP IPDT technologies would be primarily in the payload for sampling, in situ analysis, etc.. The Champollion lander would be minimally changed from its Rosetta configuration.
- **HIGH-TECHNOLOGY CARRIER WITHOUT CHAMPOLLION LANDER TO TEMPEL 1 IN 2003**
  - High technology spacecraft with NMP IPDT technologies in the carrier and in the payload. Without the Champollion lander, the payload mass requirements are lower. The additional capability could be used to reduce cost, increase redundancy, or validate additional NMP IPDT technologies.
- **HIGH-TECHNOLOGY CARRIER TO NEAR-EARTH ASTEROID OR PHOBOS / DEIMOS IN 2003**
  - Further reduction in cost might be achieved by changing from SEP to chemical propulsion, but at the expense of available targets. May be only able to reach Near-Earth asteroids. Available payload mass would be limited. The Champollion lander would not be carried on this type of flight.
- **FULL-UP SAMPLE RETURN IS A SEPARATE SUBOPTION FOR EACH CASE**

OPERATIONAL SCENARIO
COMET RENDEZVOUS / MAPPING



Far Approach Phase (~17 days):
Capture comet on camera, update ephemeris

Near Approach Phase (~15 days):
Measure comet mass, nominal shape, spin rate, rotational dynamics.
Measure far-field outgassing.

Transition Phase (~10 days):
Create global surface maps (10 m resolution), improve spin state and gravity estimates. Characterize outgassing. Choose candidate landing sites.

Near Comet Phase (~20 days):
Map selected surface areas of comet to 20 cm resolution through series of closer flybys to support precision landing.

Sample Acquisition / Lander Delivery Phase (~15 days):
Place carrier in orbit suitable for delivery of the IPDT sample acquisition technology to comet. Acquire sample and package via IPDT developed technology on orbiting carrier for return to Earth.
If carrying Champollion, separate lander which navigates to selected landing site. Descent <3 hours.

Landed Phase (~3 days)
For the Champollion lander mission use carrier as data relay and real-time commanding if needed.

Rc for Tempel 1 estimated at 3-4 km

DS5
PIGGYBACK TECHNOLOGY VALIDATOR

- **TECHNOLOGY VALIDATION CANDIDATES**
  - Venus or Mars aerobot
  - Micro rover
  - Micro lander / penetrator
  - In situ experiment
  - Solar sail spacecraft
  - Inflatable optical mirror demo
  - Inflatable antenna
- **MISSION DEFINITION STRATEGY**
  - In order to quickly develop a number of different mission concepts with minimal resources, the following approach will be employed. The ADT will issue a general call for ideas and proposals from interested parties that are consistent with the high priority capability needs specified by the NMP SWG and fit within the NMP programmatic constraints.
  - The ADT will compile the responses and meet with the proposers to help refine the mission concepts. (This process has already begun).
- **DS5 DESIGN TEAM**
  - DS5 ADT Study Lead is Steve Cornford.
  - The ADT will solicit help from a wide range of technology and advanced mission planners.

CANDIDATES FOR THE NEXT EARTH ORBITING VALIDATION FLIGHT

MISSION THEMES

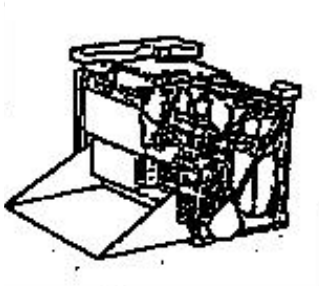
- In September 1996 the NMP Science Working Group developed a set of Earth orbiting Mission Themes from which the next NMP Earth orbiting mission (EO2) will be selected.
    - Nadir atmospheric sounding
    - Tropospheric sounding with LIDAR
    - Earth imaging with SAR
    - Atmospheric limb sounding with GPS
    - Soil moisture
    - Atmospheric chemistry
    - Geostationary
- Following a NASA HQ meeting in December 1996, a recommendation was made to augment the NMP SWG with additional members from the Mission to Planet Earth (MTPE) community.
- A telecon with the new MTPE SWG members is planned for February 7th in order to reassess the Mission Theme list indicated above.

EARTH ORBITING PLANS AND STATUS

- **NADIR ATMOSPHERIC SOUNDING**
  - Currently in the process of developing a mission concept based upon a stripped-down (technology demonstration) version of the IMAS (Integrated Multispectral Atmospheric Sounder) instrument. (ADT Study Lead is Juan Ayon)
- **TROPOSPHERIC SOUNDING WITH LIDAR**
  - Currently in the process of investigating four different types of LIDAR missions (Clouds and Aerosols, Tropospheric Chemistry, and Coherent and Noncoherent Tropospheric Winds). A workshop to review the various LIDAR mission concepts is planned for late February. (ADT Study Lead is Ron Salazar)
- **EARTH IMAGING WITH SAR**
  - Currently in the process of developing and defining a technology validation SAR mission - largely based upon earlier JPL SAR studies. (ADT Study Lead is Ron Salazar)
- **ATMOSPHERIC LIMB SOUNDING WITH GPS**
  - Currently beginning the development of a mission concept involving multiple microspacecraft.
- **SOIL MOISTURE**
  - Will investigate inflatable and sparse array microwave antenna mission concepts.
- **ATMOSPHERIC CHEMISTRY**
  - Electronic (virtual) workshop planned for mid February 1997 to review and update detailed capability needs of future atmospheric chemistry missions.
- **GEOSTATIONARY**
  - Workshop planned for mid February 1997 to address NOAA and new EOS measurement needs (meteorological, chemistry).

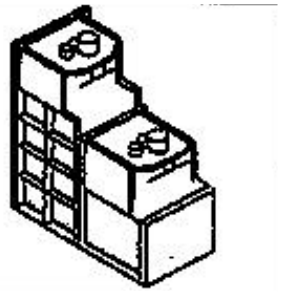
NADIR ATMOSPHERIC SOUNDER COMPARISON

AIRS



- 3.7 - 15.4 MICRONS
- 156 kg, 256 W
- 0.5 X 0.5 X 0.5 m

AMSU-A1

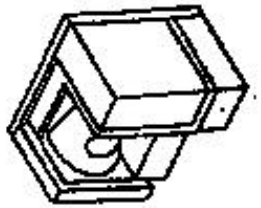


- 50.3 - 57.3, 89.0 GHz
- 51 kg, 77 W
- 0.3 X 0.7 X 0.6 m

AMSU-A2

- 23.8 - 31.4 GHz
- 42 kg, 26 W
- 0.7 X 0.6 X 0.6 m

MHS/HSB

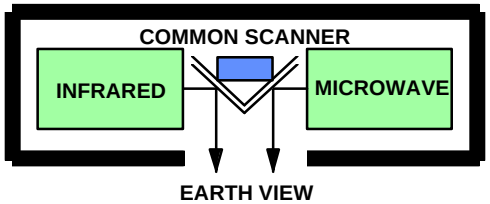


- 89 / 166 / 183 GHz
- 66 kg, 85 W
- 0.6 X 0.6 X 0.4 m

Total Mass - 300 kg, Total Power - 400 W

TECHNOLOGY INFUSION

Integrated Atmospheric Multispectral Sounder (IMAS)



Total Mass - 95 kg, Total Power - 100 W

NMP IMAS Tech Demo Version

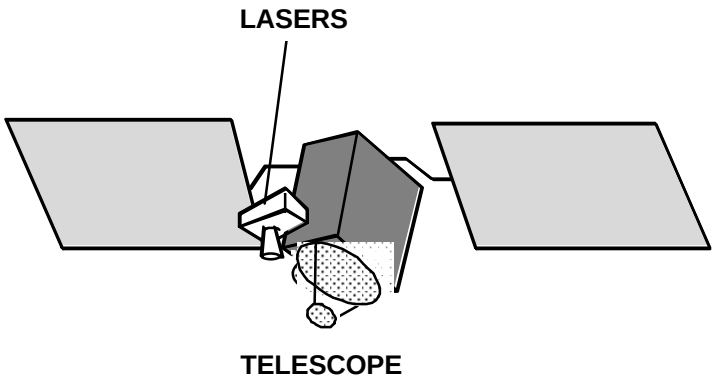
IMAS - NADIR ATMOSPHERIC SOUNDER

- **KEY OBJECTIVES**
  - To demonstrate the technology to enable 1K / 1km temperature sounding under low humidity conditions.
  - To demonstrate integrated / concurrent IR and microwave sounding.
  - Validate microwave sounding at 118 and 183 GHz.
  - Validate multi-zone passive thermal control design.
- **GENERAL MISSION CHARACTERISTICS**
  - Orbit: 504 - 824 km altitude (824 km is desired), sun-synchronous inclination, 1:30 p.m. descending nodal crossing time (same as EOS PM-1), 16 day repeat cycle
  - Launch Vehicle: LMLV-1 class
  - Launch Date: 2001
  - Mission Duration: 12 months
  - Data Strategy: Data collection: 1 orbit/day @ 30 kbps
    Mass storage: Sized to allow 7 orbits of data
    Downlink scenario: Transmit data to ground every 3-7 days using 8.5 min pass from 824 km orbit
  - Operations Assumptions: Uplink / downlink using LEO-T terminals (or other small antennas)

IMAS TECHNOLOGIES - NMP OPTIONS

NM Flight Options	Technologies Demonstrated													NOTES
	Light Weight Structures					Instrument Computer	Microconnectors	Silicon on Isolator (SOI)	MMICs	Light Weight Optics	LWIR (QWIPs)	All IR Bands		
Full Flight Unit	•	•	•	•	•	•	•	•	•	•	•	•		Would provide full *functionality* of an operational instrument while taking advantage of reduced mission life
Reduced IR Coverage	•	•	•	•	•	•	•	•	•	•	•			Only provide IR data in the longest wavelength where new detector technologies are needed
	•	•	•	•	•	•	•	•	•	•			•	No IR data, but a visible area array would monitor the spectrometer focus and alignment stability during orbital thermal changes
Deleted IR Spectrometer	•	•	•	•	•	•	•	•	•					stability
Other Options	?	?	?	?	?	?	?	?	?	?	?	?		**?**

TROPOSPHERIC SOUNDING WITH LIDAR

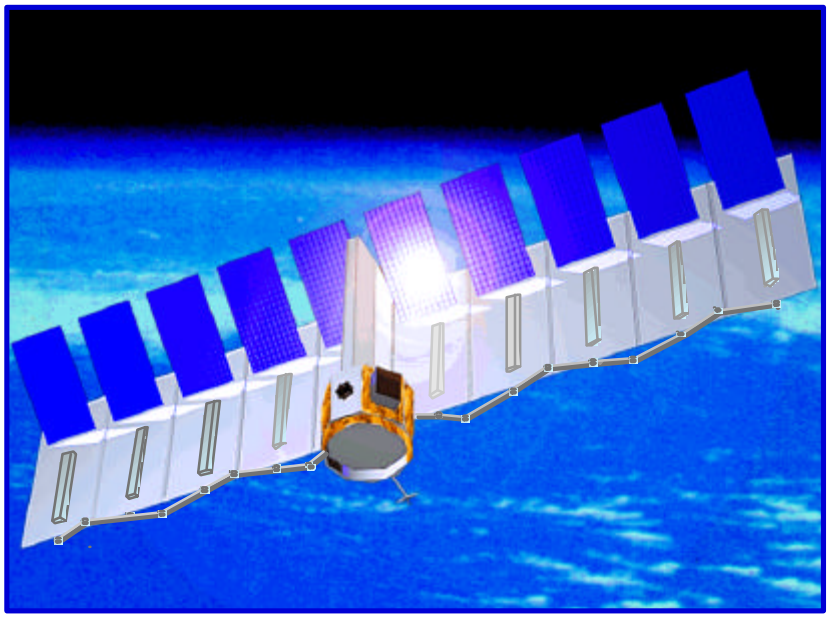


- **KEY OBJECTIVES**
  - To demonstrate advanced lightweight LIDAR components
  - To demonstrate advanced spacecraft power components
- **SCIENCE OBJECTIVES**
  - Active sounding of the troposphere
    - Winds
    - Clouds and Aerosols
    - Chemistry
- **GENERAL MISSION CHARACTERISTICS**
  - Launch Vehicle: SELVS II class
  - Mission Duration: 6-12 months
  - Orbit: 300-500 km, Inclination > 60 deg
- **TECHNOLOGY DEMONSTRATION OPTIONS**
  - Wind LIDAR
    - Coherent
    - Noncoherent
  - Cloud / Aerosol LIDAR
  - Tropospheric chemistry
    - Deployable telescope

LIDAR MISSION OPTIONS

Title ----> Characteristics	Cloud & Aerosol	Coherent Doppler Tropospheric Wind	Tropospheric Chemistry	Incoherent Doppler Tropospheric Wind
Organization	LaRC (Winker et.al.)	MSFC (Kavaya et. al.)	LaRC (Browell et.al.)	GSFC(Gentry et. al.)
Expected performance -wind velocity resolution -??	 N/A ? ??	 0.5 m/s ??	 N/A ? ??	 0.5 m/s ??
Laser type	Nd: YAG	Ho: YLF	Ti: Sapphire	Nd: YAG
Laser energy (J)	0.3 at 532 nm 0.17 at 1064 nm	0.2 to 0.5 at 2065nm	?? 300 to 1100 nm	1-2 at 1064nm
Laser pulse repetition frequency (Hz)	10	5-10	10 ?	20
Laser pulse-width (ns)	30	500	??	15
Vertical resolution (km)	0.1 ?	0.25 ?	1	0.25 ?
Horizontal resolution (km)	100 ?	100	100	500 ?
Aperture size (m)	0.9	0.5-1	1-3 (deployable)	1
Scanning strategy	nadir viewing	30° conical scan	nadir viewing ?	45° conical scan ?
Overall envelope (m^3)	1-1.5	1-1.5	2	1-1.5
Weight (kg)	150-200	200-250	178	200-250
Power consumption (W)	200	250-400	250	250-400
(JPL) Estimated cost ($ M) (no reserves, no post launch)	15 ± 2	17 ± 2.5	16 ± 2	15 ± 2
Desired platform (host s/c)	??	Shuttle (attached)	??	??
Orbit type (preferred)	non- Sun-synchronous	non- Sun-synchronous	non- Sun-synchronous	non- Sun-synchronous
Orbit altitude (km)	400-500	300	500	500
Orbit inclination (degree)	45-60	30-60	> 60	> 60
Instantaneous data rate (Mbps)	0.4	20	1	1
Data duty cycle	??	??	??	??
Data volume (Gb/day)	??	??	??	??
Data Storage (Gbytes)	??	??	??	??
S/C Attitude control (mrad)	10	1.8	10	??
S/C Attitude knowledge (mrad)	2	0.05 (over 5 ms)	2	??
Technology readiness level (1-9)	??	??	??	??

EARTH IMAGING WITH SAR

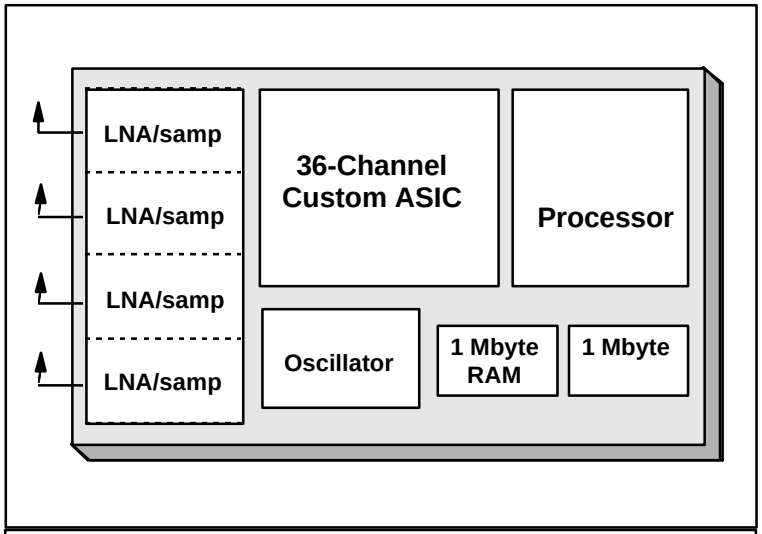


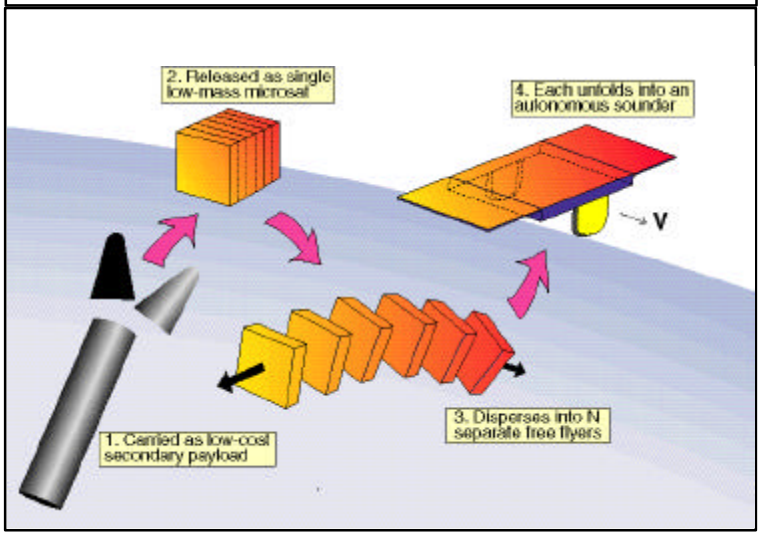
RADAR INSTRUMENT TECHNOLOGY
- MEMS based RF electronics
- Mixed signal / multi-mode ASICS
- Very high speed DSP / FPGA digital electronics
- Lightweight deployable antenna / structure
- Partial on-board data processing

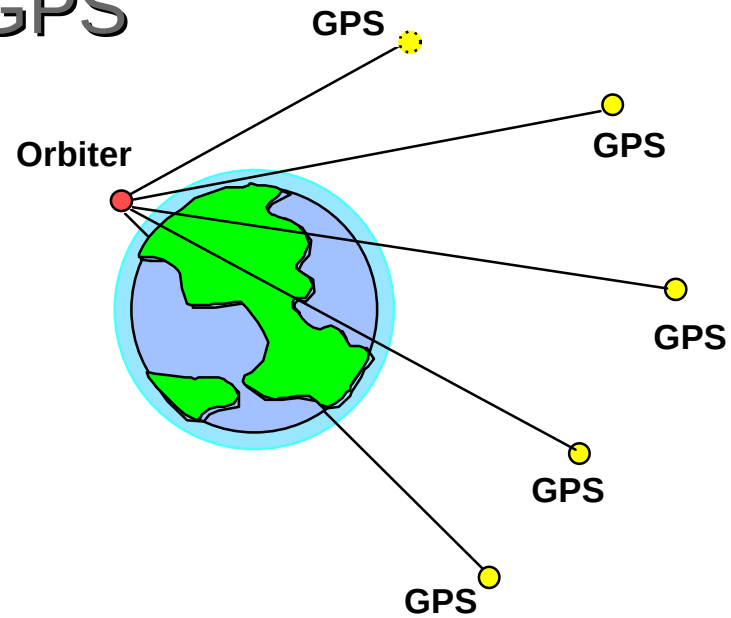
FLIGHT SYSTEM TECHNOLOGY
- Miniature high volume on-board data storage
- Target reference pointing control system
- Optical communications

- **KEY OBJECTIVES**
  - To demonstrate advanced lightweight SAR components
  - To demonstrate high rate downlink and high capacity on-board storage
- **SCIENCE OBJECTIVES**
  - Land topography and topographic change measurement
  - Biomass mapping
  - Hazard monitoring
- **GENERAL MISSION CHARACTERISTICS**
  - Launch Vehicle: SELVS II class
  - Mission Duration: 6-12 months
  - Orbit: 600-800 km, Inclination = sun-synch
- **TECHNOLOGY DEMONSTRATION ELEMENTS**
  - Lightweight electronics
  - Inflatable or deployable antenna
  - Spacecraft and ground components
    - Autonomous operations

ATMOSPHERIC LIMB SOUNDING WITH GPS







SPECIFICATIONS
Mass: <300 g
Volume: 10 x 6 x 1 cm
Power: 1.5 w, avg; 3.0 w, peak
Cost: <$25K (single units)
Phase precision: <0.2 mm (1 s)
Design Life: 5 yrs
Other: 12-sat tracking
Dual frequency (L1/L2)
P-code & codeless
Recurring Cost To Orbit of Satellite = $100K

KEY TECHNOLOGIES
Low-power MMIC RF chips
Low-power 36-channel ASIC
Low-power, high-speed processor
Channels expandable in units of 12
Antennas expandable in units of 4
Full Autonomy: Satellite acquisition, OD/AD, occultation scheduling,...
Anomaly detection/correction
GPS integrity monitoring

REMAINING EARTH ORBITING MISSION DEFINITION ACTIVITIES

REMAINING MISSION THEMES

- Mission definition activities have not yet begun for the following Earth orbiting Mission Themes. They will be addressed as soon as the other studies are completed and/or new information becomes available (i.e. from upcoming workshops).
    - Soil moisture
    - Atmospheric chemistry
    - Geostationary

ADT / IPDT INTERFACE

- **IPDT TECHNOLOGIES FOR FUTURE MISSIONS**
  - The ADT needs to receive from each of the IPDTs a list of candidate technologies for the future deep-space and Earth orbiting missions.
  - The ADT will focus first on the Category I technologies (i.e. the mission defining technologies). Later, Category II and III technologies will be incorporated into the mission architectures.
- **ADT / IPDT INFORMATION TRANSFER**
  - More work needs to be done to define the proper mechanism (template?) for information to be transferred effectively and efficiently from the IPDTs to the ADT.
    - Should the ISX IPDT Roadmap tool be used to transfer the data?
      - Preliminary answer is yes.
    - If yes, should it be modified to include different data types?
      - Yes. Work is in progress to define the additional parameters.
    - This is a topic for Break-Out Group #4.