NASA's Deep Space 1: Rocketing to the Future

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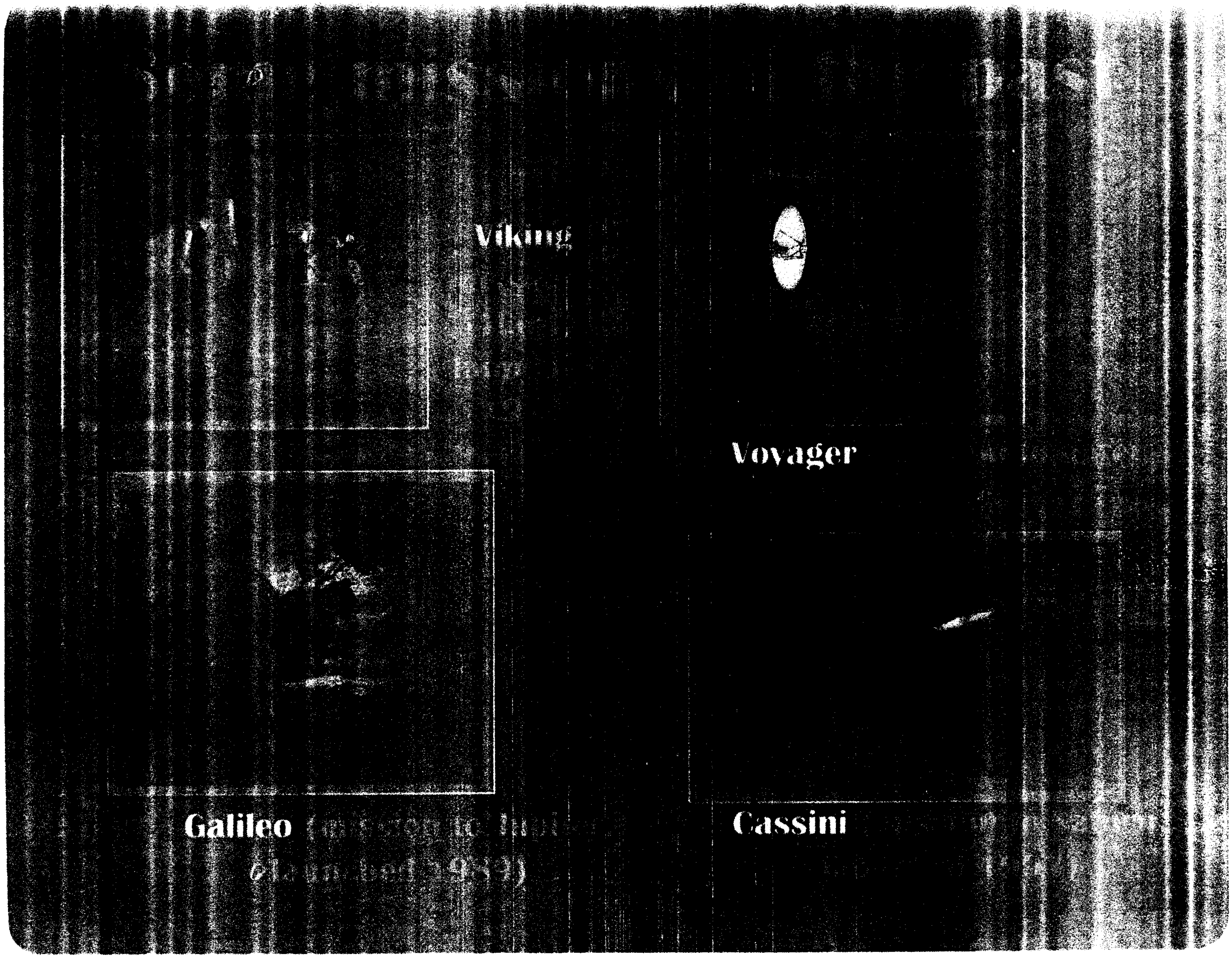

Viking
Voyager
Galileo
Cassini

New Millennium Program

Objective:

- Flight validate advanced technologies to help enable NASA's plans for space and Earth science programs.

Technology selection criteria:

- Present a high risk to the first user.
- Require in-flight validation.
- Reduce cost and risk of future programs.
- Represent a significant improvement over state of the art.

Technology validation:

- Assess the applicability of the technology product to those programs.
  - Elucidating the limitations of an advanced technology is valuable.
- Diagnose in-flight failures or anomalies.

DS1 Complete Mission Success Criteria

1) Demonstrate the in-space flight operations and quantify the performance of the following advanced technologies:
   - Solar electric propulsion
   - Solar concentrator arrays
   - Small deep space transponder
   - Miniature camera and imaging spectrometer
   - Autonomous navigation

   and 3 of the 6 following advanced technologies:
   - Autonomous remote agent
   - Beacon monitor operations
   - K_a-band solid state power amplifier
   - Low power electronics
   - Multifunctional structure
   - Power actuation and switching module

2) Acquire the data necessary to quantify the performance of these advanced technologies by September 30, 1999. Analyze these data and disseminate the results to interested organizations/parties by March 1, 2000.

3) Utilize the on-board Solar Electric Propulsion (SEP) to propel the DS1 spacecraft on a trajectory that will encounter a near-Earth asteroid in FY 1999.

4) Assess the interaction of the SEP system operations with the spacecraft and its potential impact on charged particle, radio waves and plasma, and other science investigations on future SEP propelled deep space missions.

DS1 Technology Payload

- Solar electric propulsion
  - Provided by NSTAR (NASA SEP Technology Applications and Readiness) Program
  - 2.5 kW $\leftrightarrow$ I_{sp} = 3100 s; throttle in discrete steps to 0.5 kW $\leftrightarrow$ I_{sp} = 1900 s
  - Diagnostics sensors for E and B, energy and density of electrons and ions, and surface contamination

- Solar concentrator array
  - Provided by BMDO
  - Arrays of cylindrical Fresnel lenses over strips of $GaInP_2$/GaAs/Ge
  - 2.5 kW at 1 AU BOL

- Miniature integrated ion and electron spectrometer
  - Energy and angle analysis for electrons and ions
  - Ion mass analysis
  - Microcalorimeter

- Miniature integrated camera and imaging spectrometer
  - 2 visible imaging channels
  - IR and UV imaging spectrometers
  - Shared 10-cm primary mirror

DS1 Technology Payload (Cont'd)

- Autonomous optical navigation
  - Acquisition and processing of images of asteroids against stellar background
  - Orbit determination
  - Maneuver design and execution
  - Direct commanding of IPS, MICAS, and ACS

- Remote agent
  - Planner/scheduler to generate a set of activities
  - Executive to expand that to a sequence of commands and to monitor their execution
  - Mode identification and reconfiguration

- Beacon monitor operations
  - Summarization of spacecraft health data and transmission of 1 of 4 tones to indicate urgency of request for ground action

- Small deep-space transponder
  - X-band receiver, X-band and K_a-band exciters, CDU, TMU, and beacon tone generator

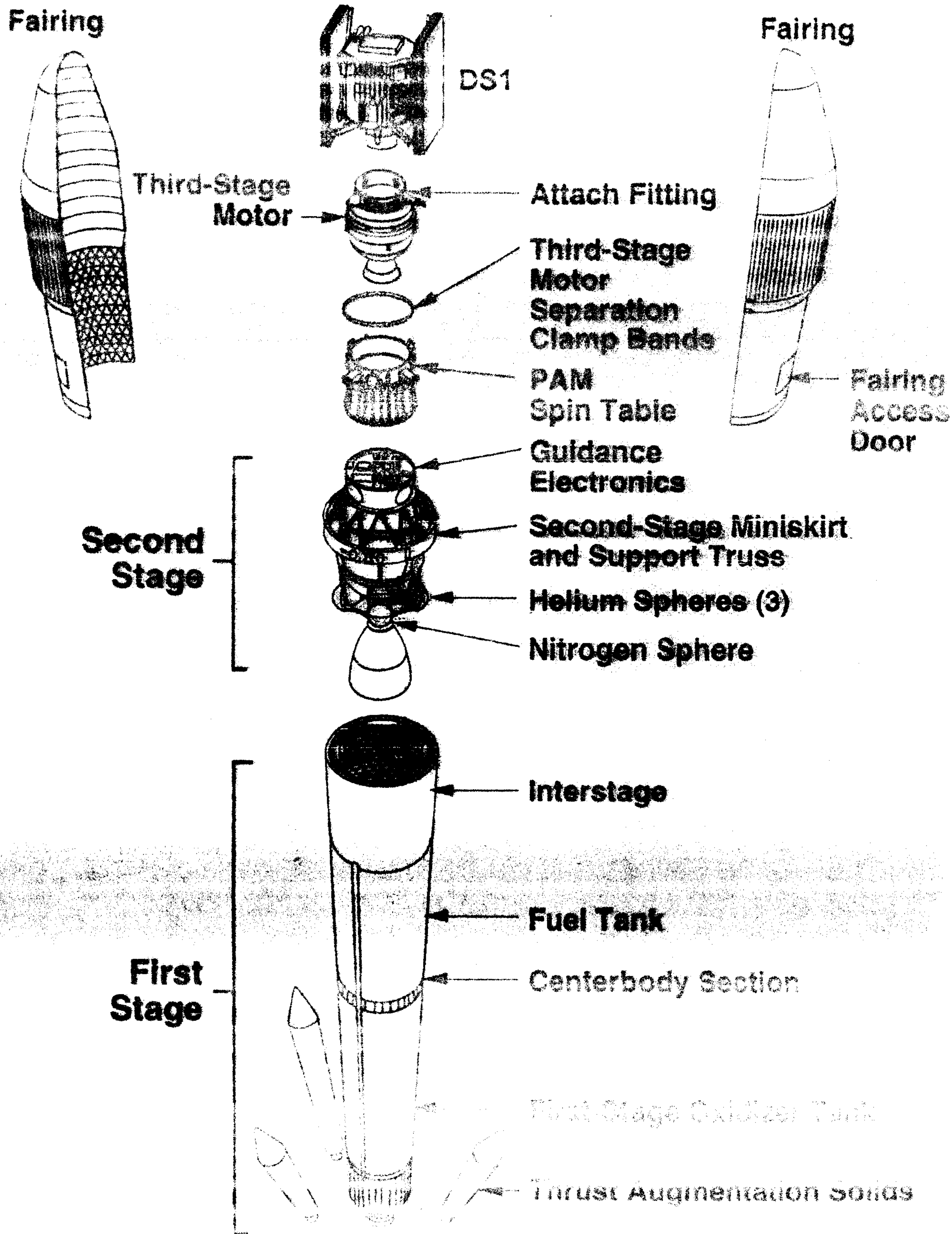
- K_a-band solid state power amplifier
  - Enabled K_a-band downlink telecommunications tests and DSN system tests

DS1 Technology Payload (Cont'd)

- Power actuation and switching module
  - Power switch using high-density interconnects with mixed signal ASIC controller

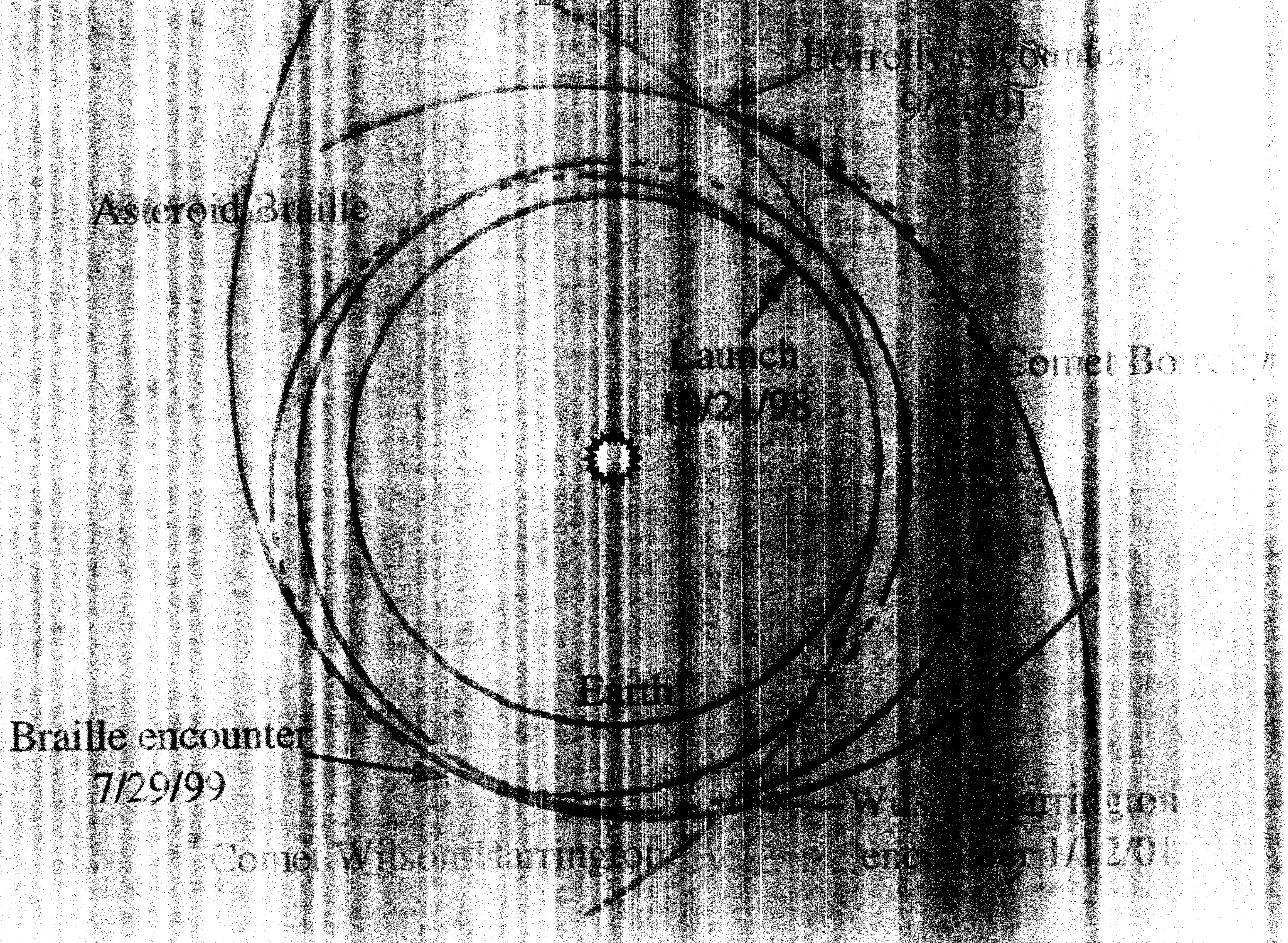
- Low power electronics
  - 0.9 V logic, 0.25 μm feature size

- Multifunctional structure
  - Electronics integrated into load-bearing structural element



Fairing
DS1
Fairing
Third-Stage
Motor
Attach Fitting
Third-Stage
Motor
Separation
Clamp Bands
PAM
Spin Table
Fairing
Access
Door
Guidance
Electronics
Second
Stage
Second-Stage Miniskirt
and Support Truss
Helium Spheres (3)
Nitrogen Sphere
Interstage
Fuel Tank
First
Stage
Centerbody Section
Thrust Augmentation Solids

Deep Space 1 Trajectory



Technology Benefit Example

- Mission concept:
  - Same encounter targets as DS1 for primary and extended missions
  - Standard technologies with similar functionality:
    - N_2O_4/MMH propulsion system
    - Scaled solar array
    - Mars '98-class telecommunications system
    - Cassini-class plasma spectrometer
    - Separate visible imager and IR push-broom spectrometer

	"Standard technology" DS1	Actual DS1
Injected mass	~ 1300 kg	486 kg
Launch vehicle	Shared Atlas IIA	Shared Delta 7326

Current Alternative to SRU

- Current method of high gain antenna (HGA) pointing relies on using signal strength at DSN as error signal for pointing. Procedure:
  - Spacecraft offsets HGA from normal Sun-point by Sun-probe-Earth angle in arbitrary direction.
  - Spacecraft cones around Sun line, thus sweeping HGA through Earth.
  - Received signal at DSN reveals phase of rotation. Time of next HGA-on-Earth peak is computed.
  - Command to stop coning is transmitted (allowing for round-trip light time, time for DSN to sweep uplink frequency to acquire uplink on board, and other delays). Known lag on spacecraft is accounted for.
  - Attitude corrections sent as real-time commands as needed (~ 1/4hr).
- This technique used regularly until new software is loaded.

Replacement for SRU

- Plan under development uses visible CCD in miniature integrated camera spectrometer (MICAS) in place of SRU. Key differences between SRU and MICAS:

Parameter	SRU	MICAS
Field of view diameter	$8.8° \times 8.8°$	$0.69° \times 0.78°$
Limiting magnitude	7.5	5 – 9 (attitude dependent)
Output data	quaternion	image file
Output rate	4 Hz	0.04 Hz

- *Principal problem*: in an arbitrary attitude, the probability of a detectable star pattern being the MICAS FOV is too low.

- *Solution*: Constrain spacecraft to attitudes such that
  1) 1 and only 1 preselected star of sufficient magnitude is in the MICAS FOV, or
  2) duration at attitude is short enough to use gyros.
  - In contrast to primary mission, for remainder of extended mission, only 4 classes of attitudes are needed:
    - HGA on Earth
    - Ion propulsion system (IPS) thrust
      - New IPS thrust plan developed that uses discrete inertial thrust vectors rather than nearly continuously updated vector.
    - TCMs
    - Science data acquisition at Borrelly

DEEP SPACE 1

TECHNOLOGY • INNOVATION • EXPLORATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION