Hubble Space Telescope Presentation to the OS

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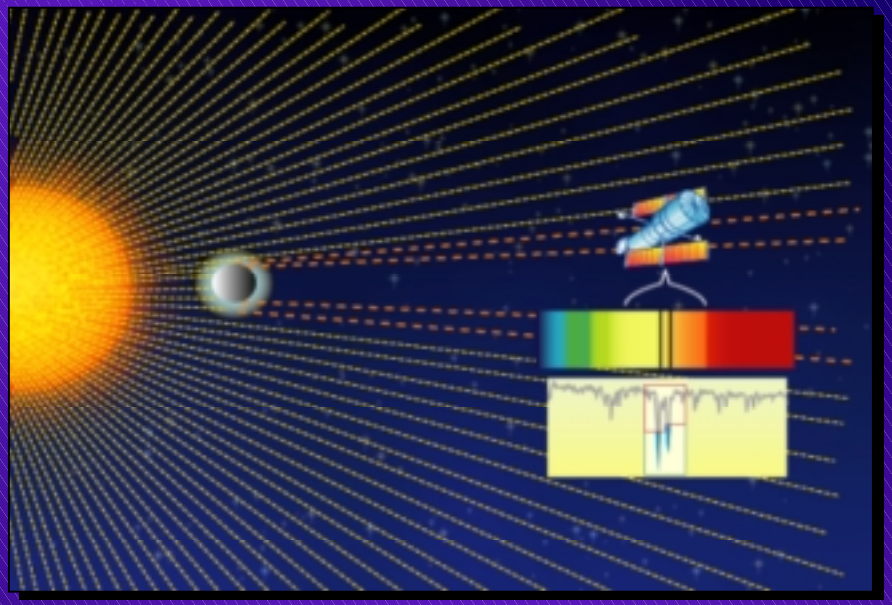
December 3, 2001

Proposals Submitted For HST Cycle 11

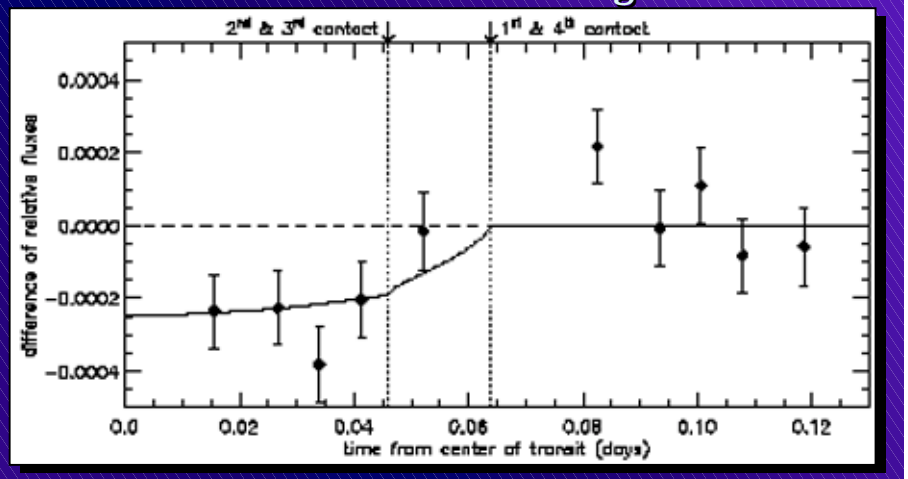
1079 Proposals Received (second most ever)

Type	#	Resources
GO	**859**	**24,679 orbits (largest request ever; 8:1 over-subscription)**
Large	41	5,554
Treasury	19	4,511
Pure Par	8	1,795
ESA	189	4,624
STScI	72	3320
SNAP	**80**	**7,359 targets (about the same as before)**
ESA	11	1,278
STScI	10	836
AR	**140**	**$12.85M (double normal requested)**
STScI	11	$1.3M
Legacy	10	$3.8M
Theory	47	$3.9M

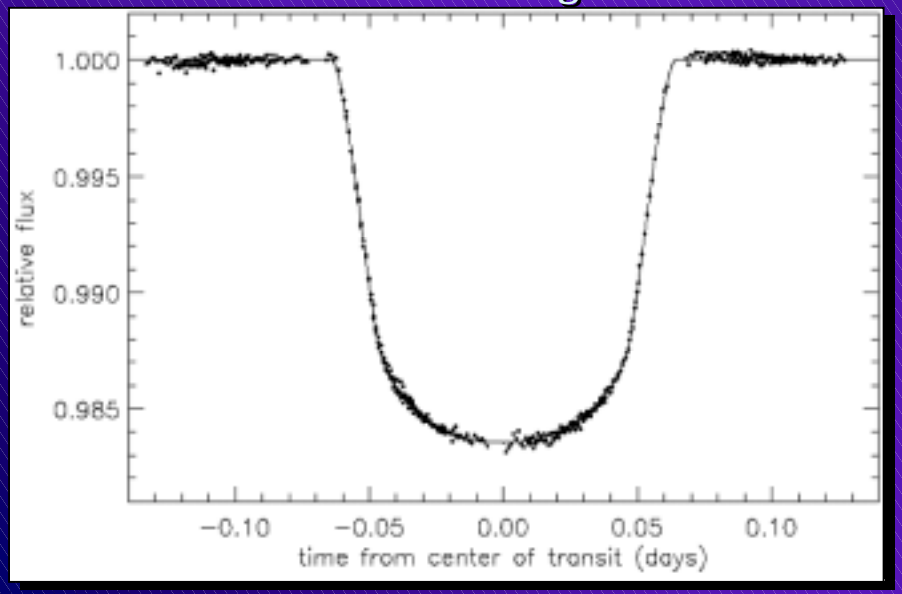
First Detection of the Atmosphere of an Extra-Solar Planet HD209458b



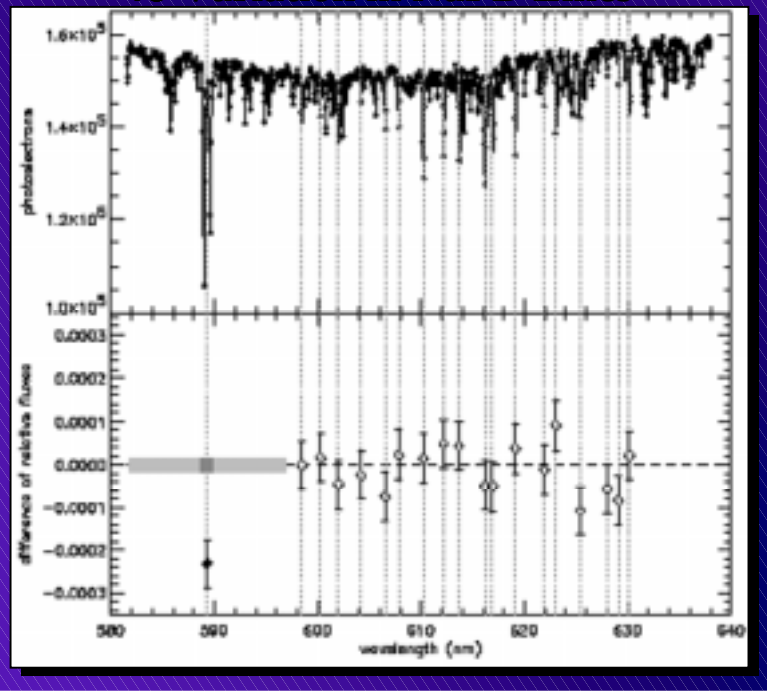
NaI D Line Variation During Transit



Broadband Transit Light Curve



4σ Variation in NaI D Lines



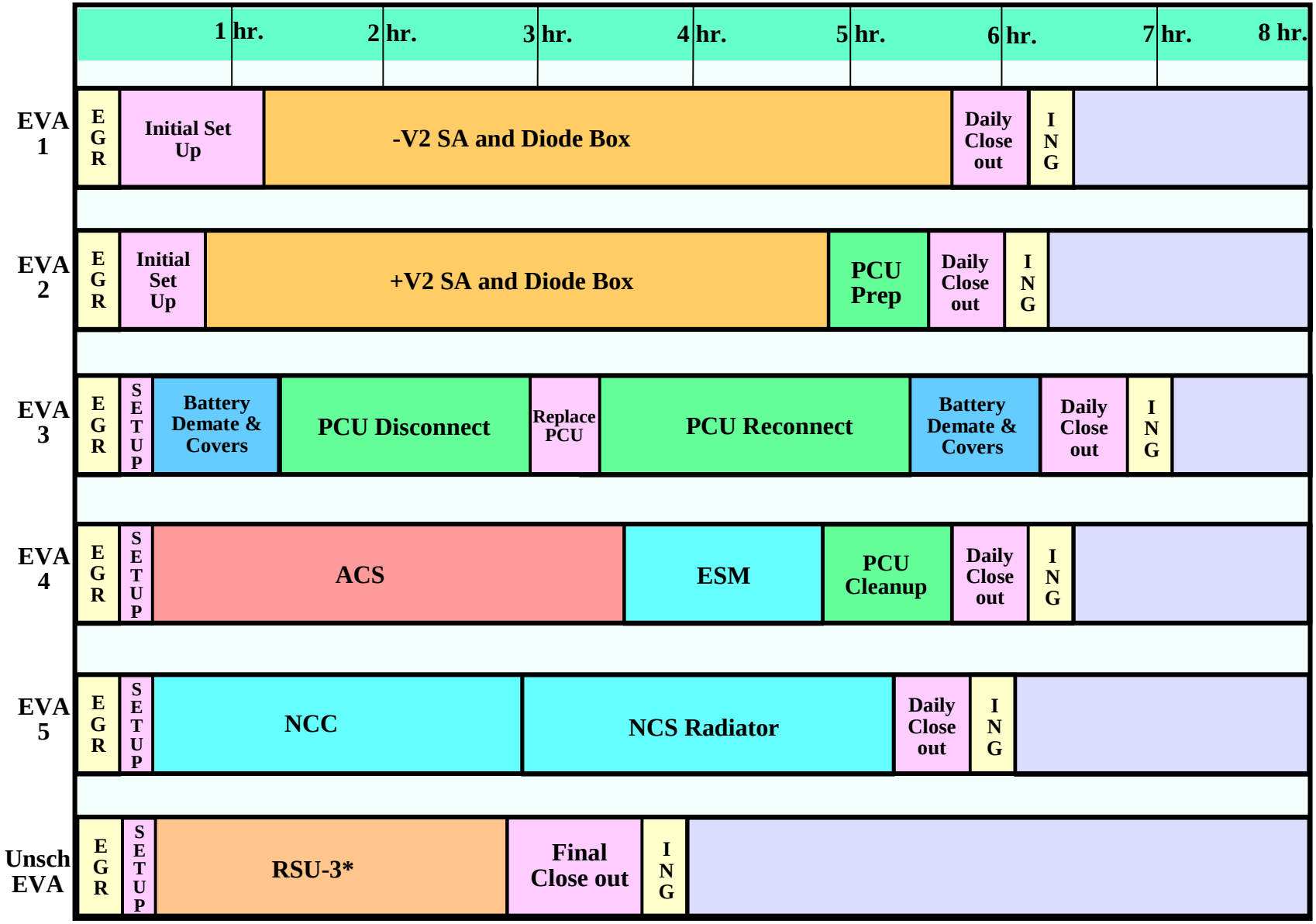
Servicing Mission 3B Summary

- **Launch Date – February 14, 2002**
- **Hardware Testing And Flight Qualification Successfully Completed**
- **ACS Final Alignment Check Completed at Ball**
  - Arrived at KSC November 28
- **NCS Remains At GSFC To Assure Cleanliness**
  - To be shipped to KSC January 10
- **Solar Arrays, PCU and All Other Flight Hardware Now At KSC**
- **All Project Mission Simulations Completed; First Two Joint Integrated Simulations Completed**
- **The HST Project Is Ready To Fly!!**

Goddard Space Flight Center

Hubble Space Telescope Program

HST SM3B EVA Scenario



Priority

1. SA
2. PCU
3. ACS
4. NCS
5. RSU-3*

*** Desirable for SM3B**

HST Servicing Strategy

Interim Report September 28, 2001

Overview

- **Servicing Strategy group was chartered by Anne Kinney of Code S in June 2001 to study HST servicing strategies until NGST era**

- **This package serves as an interim report, team must now suspend effort to focus on SM3B, will reconvene post SM3B to complete study**

<u>Findings and Recommendations</u>

- **Team recommends that SM3B and SM4 launch dates remain as presently planned, no changes identified to content for either mission**

- **Team studied several options for HST retirement, two best options will require additional study after SM3B**
  - Retrieval with Space Shuttle in 2010 (default option)
  - Installation of prop module for atmospheric re-entry or boost to parking orbit at end of science mission

- **6 month effort post SM3B to analyze/assess final two retirement options**

- **Additional 6 months to prepare implementation plan for option selected by HQ**

Core Members of Servicing Mission Study

Michael Moore	NASA HQ
Hashima Hasan	NASA HQ
Bruce Margon	ST ScI
Rodger Doxsey	ST ScI
Malcolm Niedner	GSFC Code 600
Robert Sticka	GSFC Code 300
John Gainsborough	GSFC Code 441
Bryan Fafaul	GSFC Code 442
Rud Moe	GSFC Code 442
Rick King	GSFC Code 442
Mike Weiss	GSFC Code 440
Keith Kalinowski	GSFC Code 730
Dave Scheve (Chair)	GSFC Code 440

HST Performance Until NGST Era

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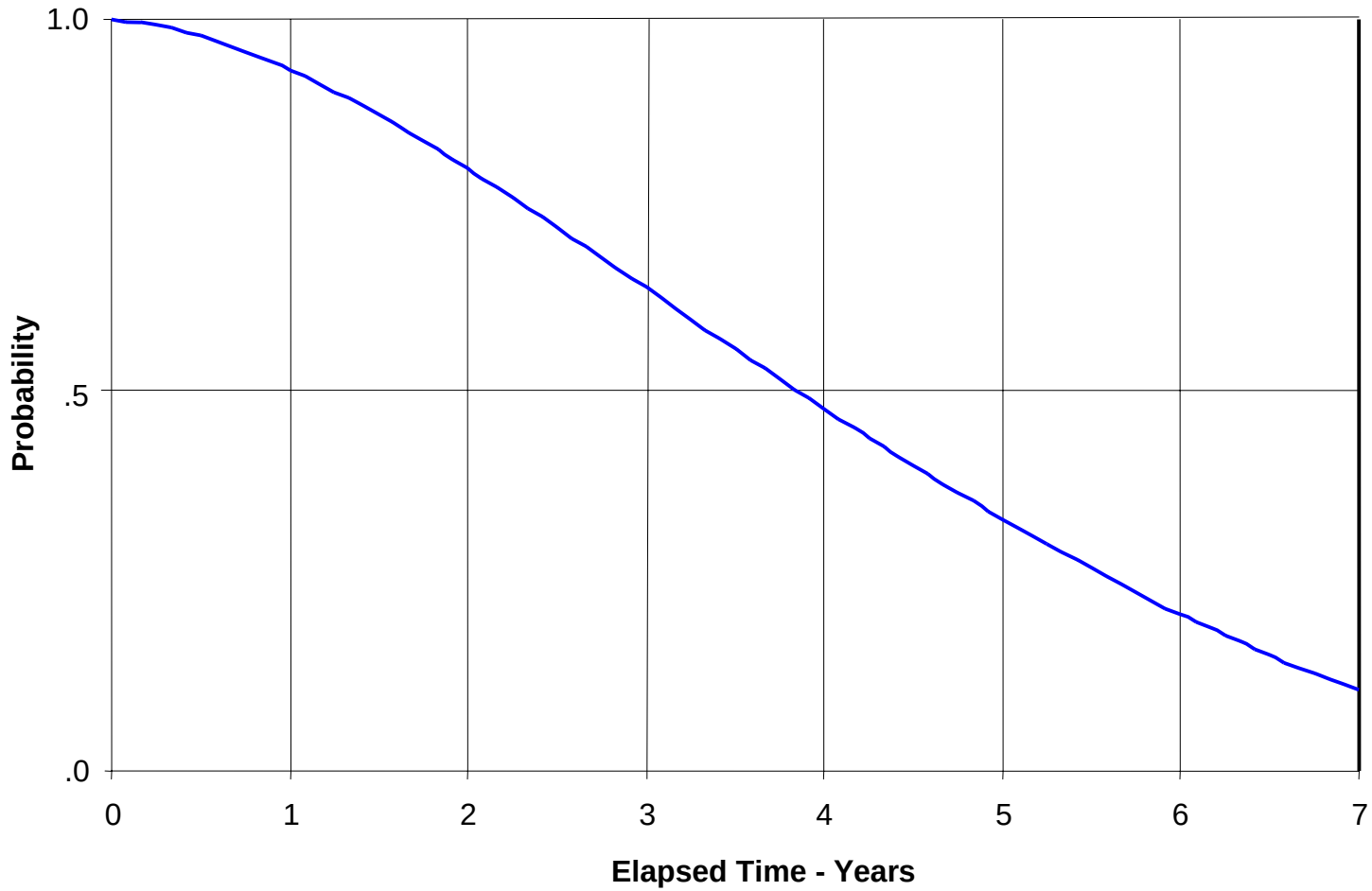
9/10/01 HST Reliability Indicator from the Refined Aerospace Corporation Model



Probability of HST Science Operations vs. Time Since Last Servicing Mission

HST Performance Until NGST Era

Summary

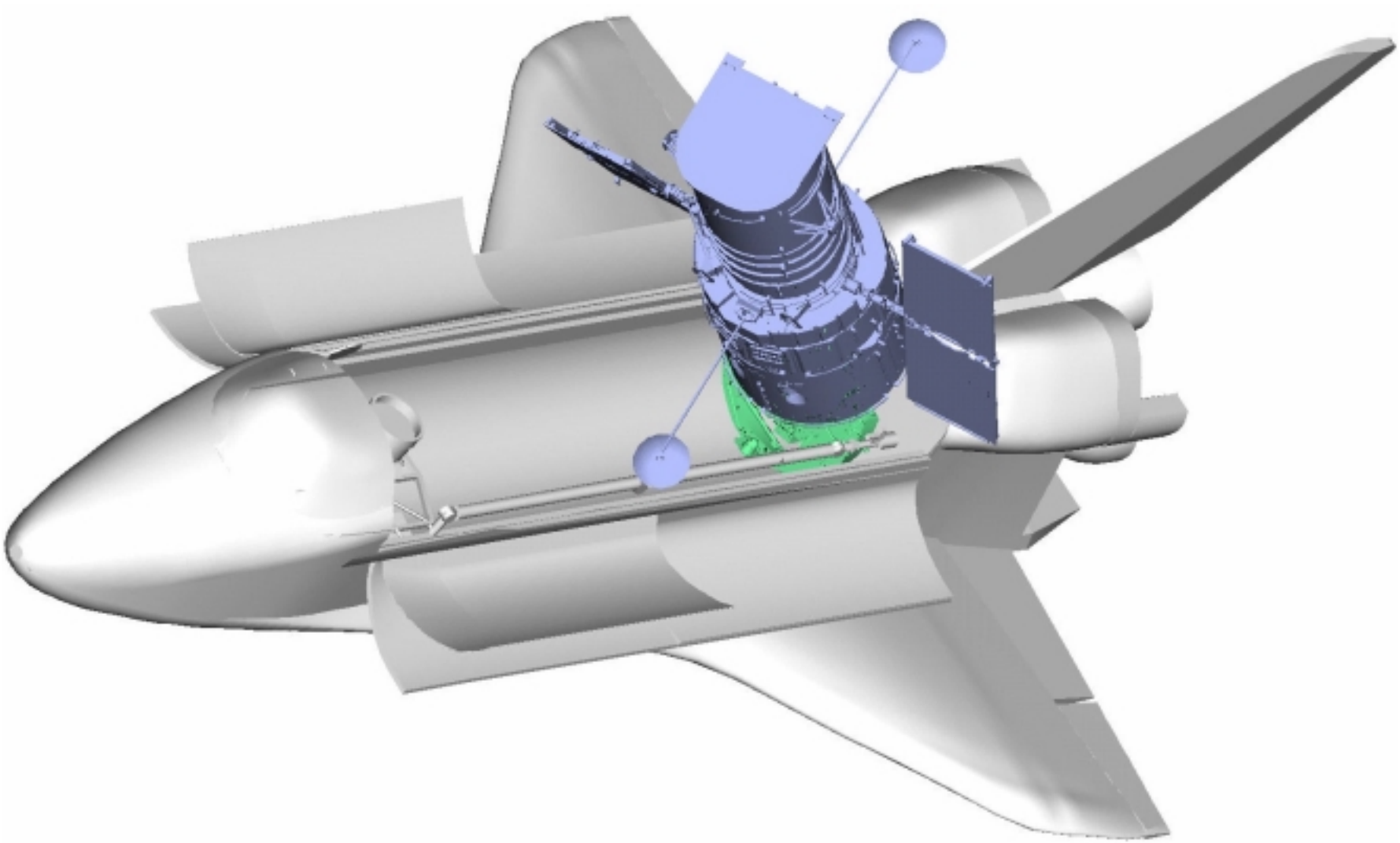
- **HST observatory/spacecraft systems have demonstrated good performance over the past 11+ years**
- **Periodic servicing on 2-3 year intervals has enabled HST's high availability**
  - Failed or degraded hardware has been replaced on every servicing mission
  - Examining HST mission history (e.g., the kinked bistem at SM1, the gyro failures before SM3A), it's safe to say that without servicing, science operations would not have survived any continuous 6-year period to date
- **HST will have a robust science instrument complement until the NGST era**
- **HST has a low likelihood of supporting science operations 6 years after the last servicing mission**

HST Retirement

HST Shuttle Retrieval

- **Retrieval mission entails removal of hardware from HST to satisfy shuttle envelope and landing load constraints**
  - Columbia is best orbiter for retrieval
  - Unorthodox servicing approach needed for orbiters with external airlock
    - Major FSS design mods and
    - Extensive RMS/EVA access assessments
  - Minimum of 4, more likely 5 EVA's to prepare HST for return to earth
  - Jettison removed hardware
  - Detailed analysis to be performed to confirm feasibility of single mission retrieval
    - Analyses to be performed after SM3B
    - Shuttle waiver on landing loads will be required

View Showing HST Position for Solar Array EVA-Removal Operations



Failures Necessitating Consideration of Early HST Retrieval

- **After one failure, the following subsystems are zero-fault-tolerant for retrieval:**
  - Communications Module
  - Telemetry Format Controller
  - Timing Interface Module
  - Oscillator
  - Multiple Access Receiver
  - Multiple Access Transmitter
  - Command Data Interface
  - Low Gain Antenna
  - Essential Bus
  - Magnetic Sensing System (for retrieval in PSEA)
  - PSEA Computer (for retrieval in PSEA)

Failures Necessitating Consideration of Early HST Retrieval

- **Key failure combinations in other subsystems produce zero-fault tolerance sooner than otherwise**
  - E.g., loss of 3 Gyros (vs. 4), after loss of 1 Retrieval Mode Gyro Assembly
- **The retrieval mission must be immediately implemented once the vehicle becomes zero fault tolerant for retrieval and must be executed before an additional failure yields total loss of a function**
  - Non-retrievability results in uncontrolled re-entry
- **Removal of the retrieval requirement (e.g.; via addition of a propulsion system) eliminates this problem**
  - Science Program can continue in single string status with the prop module

Summary

- **Team recommends that SM3B and SM4 launch dates remain as currently planned**
  - No changes identified to content of either mission
- **Two best approaches for HST retirement need further assessment**
  - Retrieve with Space Shuttle in 2010
  - Install prop module, retire at end of science mission by boosting to parking orbit or atmospheric re-entry
- **Demands of SM3B preclude completing study until after SM3B**
  - 6 month effort post SM3B to analyze and assess final two retirement options
  - Additional 6 months to prepare implementation plan option selected by HQ

SUPPLEMENTARY CHARTS

HST Observations in Next Decade will address Critical Questions

- SNIa at Z = 1-2 used as quantitative probes of non-zero cosmological constant and “dark energy”; establish epoch of transition from decelerating to accelerating universe (ACS, NICMOS, WFC3)
- Character and distribution of dark matter in galaxy clusters strongly constrained by high-sensitivity mapping of gravitational lenses; cosmic shear used to probe distribution of matter on fine scales (ACS, WFC3)
- Galaxy formation and early evolution pushed 2 mag deeper than HDF in ultra-deep surveys (ACS, WFC3); efficient wide-field surveys increase morphology and precise photometry samples by 1-2 orders of magnitude to enable more precise mapping of galaxy evolution from z>3 to the present day (ACS, WFC3)
- Galaxy evolution explored over the range z=3-7; detection of proto-galaxies out to z=10 (NICMOS, WFC3)
- Quasar absorption line systems over many sight-lines probe large scale structure, state of ionization and chemical evolution of IGM over the range z = 1-5 (COS)
- Sight-lines to distant quasars intersect extended galaxy halos and probe galaxy formation and history of metal enrichment over cosmic time (COS)
- Critical for galaxy evolution studies, wide-field UV imaging probes star formation histories and stellar populations in nearby and more distant galaxies to significantly deeper levels than previously possible (WFC3)

Discoveries unanticipated in 2001 may be as or more important!

HST Observations in Next Decade will address Critical Questions (cont'd)

- Sample of optically-detected gamma ray burst (GRB) afterglows increases sufficiently to constrain origin theories, establish relation to star formation in distant galaxies (ACS, WFC3)
- SN1987a high-speed debris rams previously ejected circumstellar ring providing a tracer of precursor star's composition and detonation products (STIS)
- High-resolution, multi-color coronagraphic imaging maps detailed structure and particle size distributions of proto-planetary disks, elucidating planet formation processes and presence of large objects; continued imaging search for mature planets (ACS, NICMOS)
- Attempted detection of atmospheres of gas-giant extra-solar planets (STIS)
- Photometric monitoring of rich star fields in search of planet occultations and planet-induced micro-lensing events (ACS, WFC3).
- Search for planet-sized objects beyond the orbits of Neptune and Pluto by measuring motions of very faint objects in the ecliptic plane (ACS, WFC3)
- Composition, origins of Kuiper Belt Objects constrained by IR photometry (NICMOS & WFC3)
- Campaigns of correlative observations with contemporary OSS missions (SIRTF, CHANDRA, SOFIA, GALEX, SWIFT, etc.), as well as with major ground-based observatories, will be common

Discoveries unanticipated in 2001 may be as or more important!

Minimum Scientific Capabilities (cont'd)

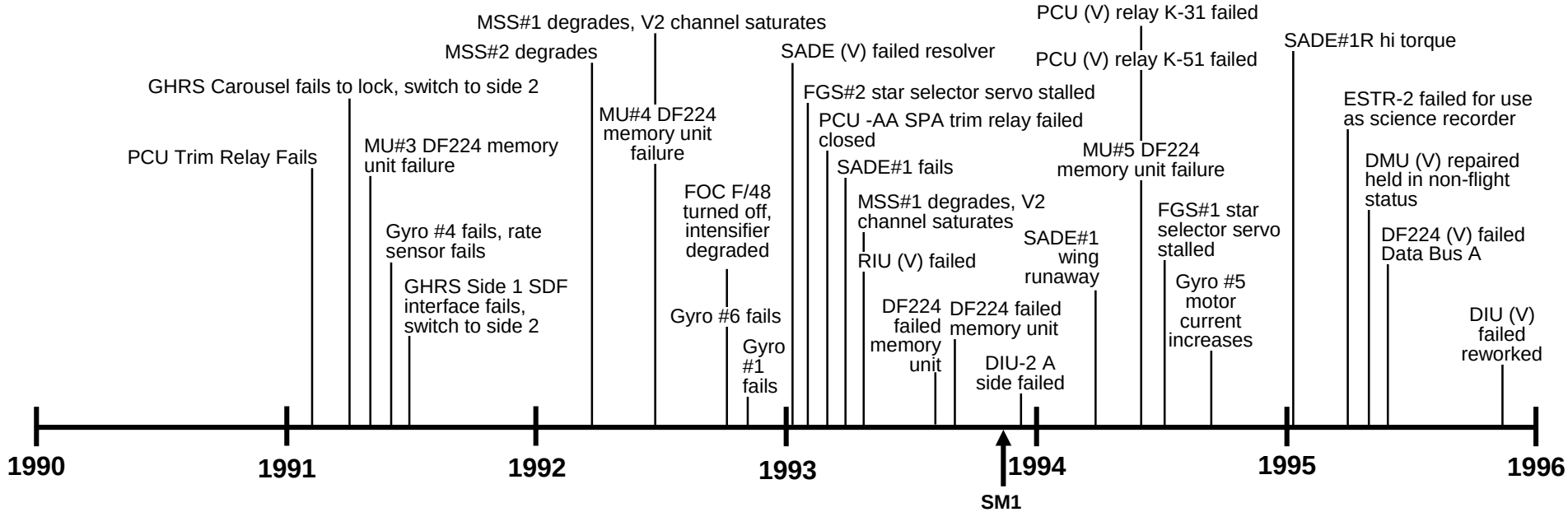
- **Prospects for survival to 2010:**
  - **NICMOS (1997):** cryocooler (2002) has no obvious limiting lifetime, but NICMOS capabilities largely subsumed by WFC3/IR; continued operations after 2004 would require power management.
  - **STIS (1997):** is now single-string electronically. CCD sensitivity degraded from CTE effects and will have lost much functionality by 2010. MAMA channels working well, radiation resistant; major life threat is loss of Side 2. Absent remedies, prospects for 2010 operations considered questionable.
  - **ACS (2002):** 2 CCD channels use photon flash method of CTE mitigation, which will provide some CTE relief. Solar Blind Channel utilizes MAMA detector. ACS will be 8 years old in 2010, but so now is WFPC2, which is still very productive. Prospects for CTE-degraded operations out to 2010 considered reasonable.
  - **COS (2004):** both channels use microchannel plates (cross delay line, MAMA detectors), which are radiation resistant. Prospects for 2010 operations considered very good.
  - **WFC3 (2004):** CCD channel uses superior charge injection process to suppress CTE effects; IR array has no obvious continuous degradation mechanism. Prospects for 2010 operations considered very good.

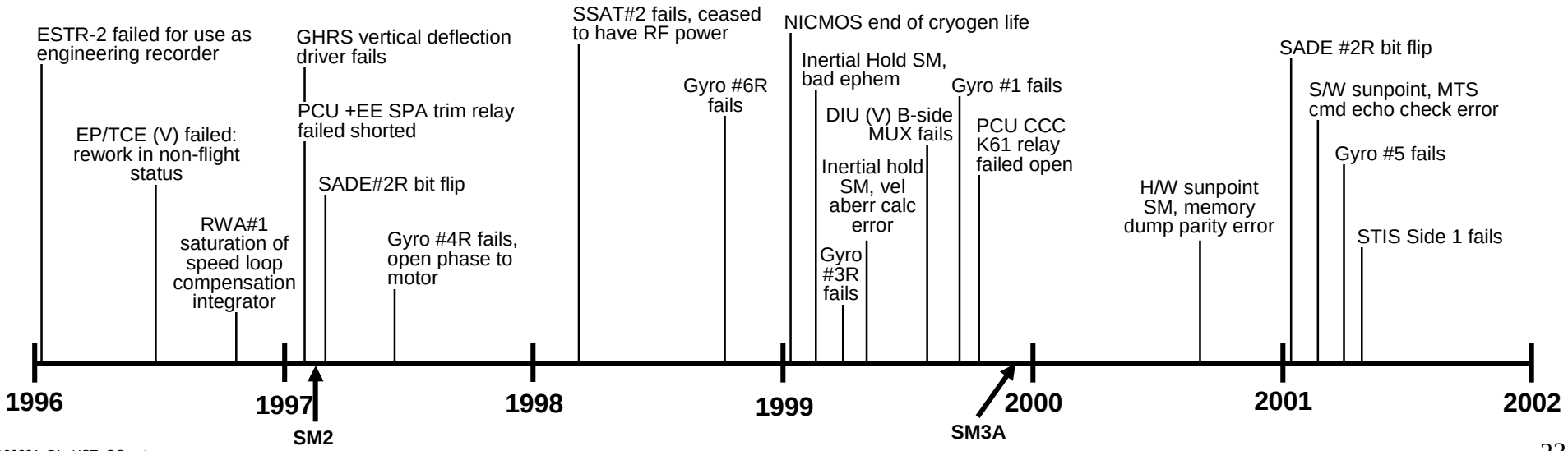
HST Performance Until NGST Era

HST Hardware Failure History

- **There have been a total of 38 failures on flight hardware since launch**
  - 29 failures on the spacecraft (including SI failures)
  - 9 failures of flight spares installed in VEST
- **Failures have been predominately random parts failures, with isolated workmanship failures (gyro hybrids), wear out/aging failures (gyro flex leads) and design deficiency (SADE 1 failure)**
- **To date, every failed hardware element has been replaced or is planned for replacement on SM3B or SM4**
- **HST is past infant mortality**
- **For the future expect principal failure mechanisms to be random electronics failures and wear out of mechanical hardware**

Hardware Failure/Safemode Timeline





HST Retirement

- **HST retirement originally slated for 2005**
- **In 1997 HST retirement moved to 2010 coincident with pre Phase-A NGST study showing NGST launch date in 2007**
- **SSG conducted preliminary study to identify end of mission options**
  - 2 options selected for final assessment after SM3B
- **HST Project will develop an EOM plan in the year following SM3B**
  - Plan will consider:
    - Disposal options
    - Debris analysis
    - Space Shuttle compatibility issues and requirements
    - EOM unique hardware requirements
    - Systems engineering and operations, and spacecraft health “triggers”

Options for HST Longevity and Retirement

	Figure of Merit / Mission Option	Maximize Science until 2010	Cost	Schedule Risk	Technical Risk
Option I	• 2010: Retrieve HST (Current Default Plan)				
Option II	• 2010: Install prop module; immediate boost to 1000+ year orbit or atmospheric re-entry				
Option III	• 2007?: Install prop module, new gyros, later boost to 500 yr orbit or re-enter atmosphere				
Option IV	• 2007?: "Light Servicing Mission" (gyros, etc.) • 2010: Retrieval Mission				
Option V	• 2007?: Light Servicing Mission • 2010: Install prop module for boost to parking orbit or re-entry				

Increasingly Favorable

Explanation of Options Chart

- **Maximize Science Until 2010**
  - Option I (Default Plan) relies on HST—last visited in 2004—to last 6 years: not likely
  - Option II improves science prospects over Option I *only if* HST operating in 2010 (not likely)
  - Options III, IV, V all augment science, but IV less so since post-2010 ops are not possible

- **Cost**
  - Monotonic progression in which number of Shuttle missions is primary driver, content is secondary
  - Cost for Options I, II will be higher if inexperienced staff does not come up to speed quickly, and will increase significantly if health/safety triggers necessitate call up of an earlier mission

- **Schedule Risk**
  - Options I and II: schedule risk not fully mitigated due to inexperienced staffing and moderate likelihood that health and safety triggers may require early call up mission
  - Option III: retrieval mission is essentially moving earlier with experienced team incorporating a prop module whose risk is manageable due to heritage prop system design
  - Option IV: 2 Shuttle missions, but the nearer one involves only things we already know well
  - Option V: 2 Shuttle missions, but the final one involves prop module

- **Technical Risk**
  - All options involving the prop module (II, III, V) considered to have medium technical risk
  - Both options w/o prop module (I, IV) are things we know how to do with the current experienced staff. The 2010 retrieval mission entails 5 EVAs and is executable with existing skills base. There is considerable risk associated with Option I for the case where a call-up mission is needed due to health and safety triggers