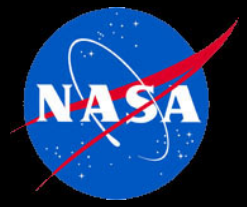


COBE (Cosmic Background Explorer) and JWST (James Webb Space Telescope) Science

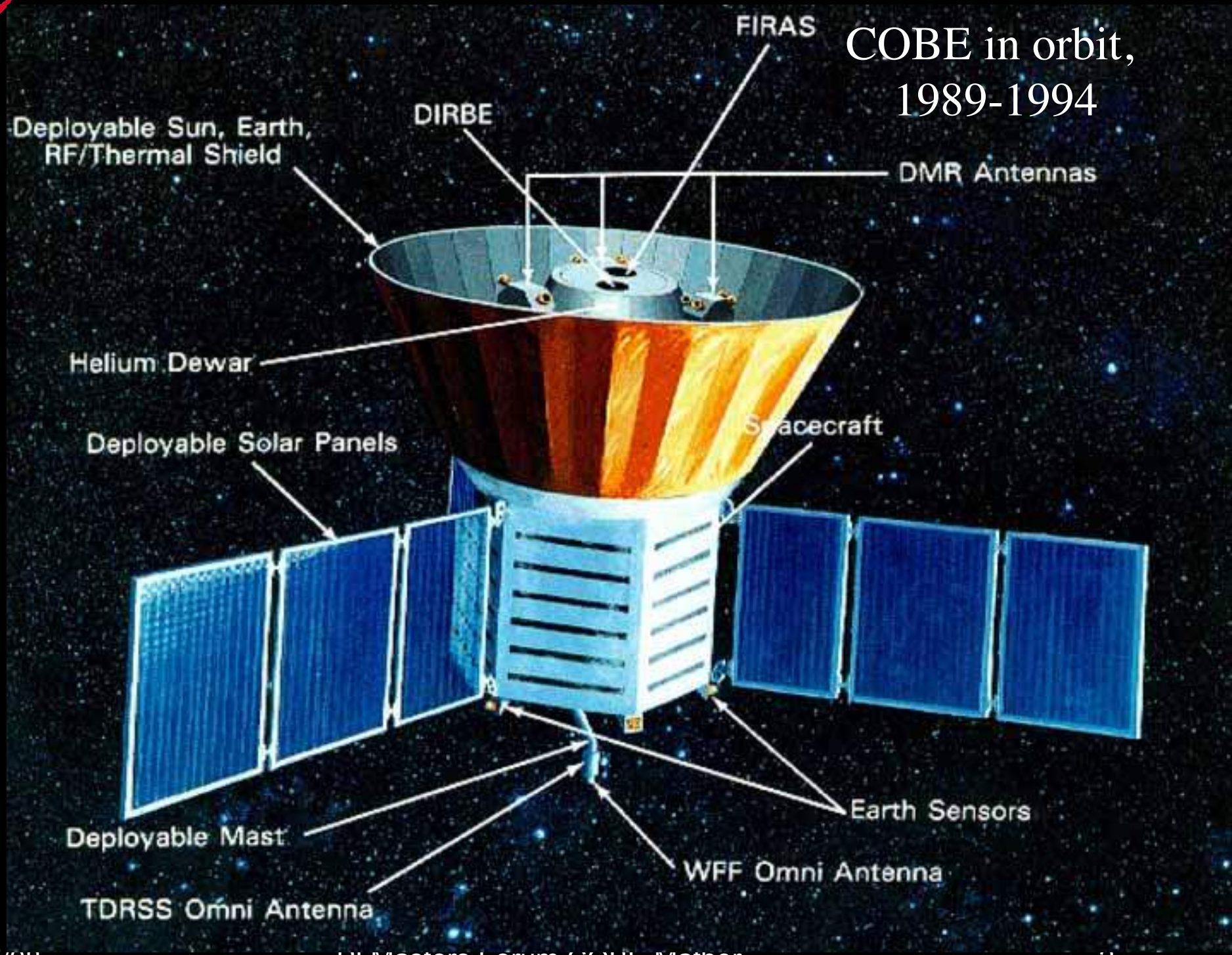
PI Masters Forum

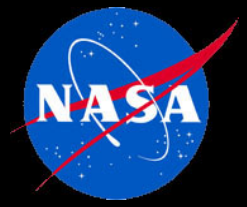
John Mather

COBE Project Scientist & FIRAS PI

JWST Senior Project Scientist

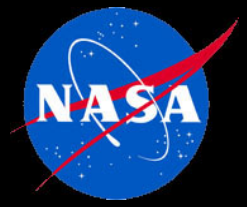
Goddard Space Flight Center


COBE in orbit,
1989-1994
FIRAS
DIRBE
Deployable Sun, Earth,
RF/Thermal Shield
DMR Antennas
Helium Dewar
Deployable Solar Panels
Spacecraft
Earth Sensors
Deployable Mast
WFF Omni Antenna
TDRSS Omni Antenna



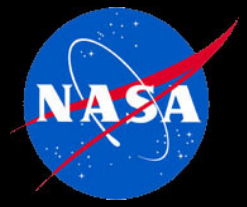
COBE Context

- Proposed 1974, before computer revolution
  - No CAD/CAM, no realistic performance modeling, can't visualize hardware before construction
  - No email, and managers couldn't type
- New Start 1982, Challenger 1986, launch 1989
- Instruments far beyond state-of-the-art
  - Detectors not available
  - Accuracy requirements unprecedented
  - Almost no cryogenic experience in space
- In-house project, largest GSFC ever did
- 2 PI's in house, 1 external (Berkeley) with in-house deputy



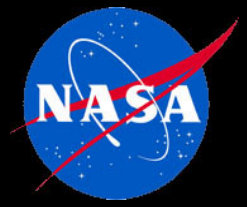
COBE Science & Engineering Team Selection

- 3 proposals submitted on CMB, 1974, out of ~150 total Explorer proposals
- Study done on spectrum experiment on board IRAS
- HQ decision to form Mission Definition Study Team: 6 members (4, 1,1) from proposals; downselect to ~12 Explorers
- Assigned GSFC to provide engineering & management - IUE team, about to launch



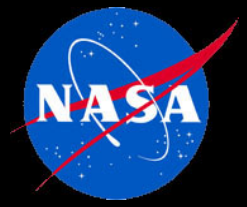
Science Team Organization

- Study Scientist drafted a Science Working Group team charter, outlining roles and responsibilities (but no process for resolving disputes or violations of policy)
- All SWG members co-I's on all instruments
- All SWG members have authorship rights on most papers for duration of mission, including coordination of press releases
- PI's have responsibility for instruments and science from them
- Chairman elected
- PI's nominated to HQ by SWG and accepted by HQ



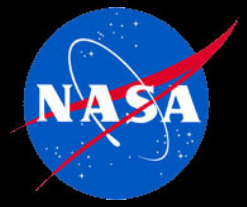
Growth of SWG to 19

- SWG members nominated additional members, and all were accepted by HQ
- Specific roles expected, not always fulfilled
- Key additions: Deputy PI's (Bennett, Kelsall, Shafer), Data Team Leader (Ned Wright)
- Only one theorist, others all instrument experts
- Note: Project Scientist is a NASA position, not a HQ-selected position, so Deputy Project Scientist is not automatically a SWG member
- Experience matters: 2 became PI's of new NASA missions (Bennett - WMAP, Wright - WISE)



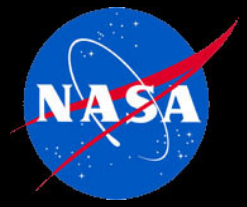
Some Science PI Lessons

- Bad idea to have Project Scientist be a PI: not enough time in a day
- Deputies essential: too much for a PI to do, and “the bottleneck is at the top”; hiring freezes (especially under Jimmy Carter) were serious issue
- PI role for in-house projects does not include financial management - but he who has the gold, rules: must be on good terms with Project Management!
- Government lab can’t delegate financial or personnel responsibility to outside PI - delicate situation for DMR PI



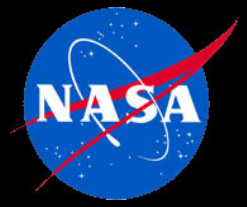
COBE Requirements

- Engineers wanted detailed requirements documents flowed down to them
- Scientists couldn’t do systems engineering all by themselves
- Systems engineers couldn’t do it without many iterations with team
  - But teams didn’t like iterations and trade studies
- Nevertheless, close interaction of scientists and engineers allowed relaxation and re-interpretation of requirements when needed
  - Pushed state of the art 1000x



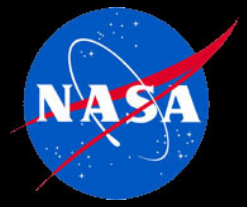
Matrix Management

- Prefer full time assignments - undivided loyalty, undivided mental concentration
- Possible with good matrix management, disrupted by bad management
- Beware assignments to organizations - prefer individuals, not “branches” or “departments”
- Scientists are “matrixed” too, typically from University environment
  - 10% time is just enough to go to meetings, not enough to do much useful
  - Better to ask for sabbaticals and release from other duties for a short period to enable concentration



Need Diversity of Personality

- Visionary - forward looking
- Decision making - taking risks for progress
- Fact checking - detail oriented
- Grouch - test everything enough
- Planning - make things happen
- Organization - proper assignments

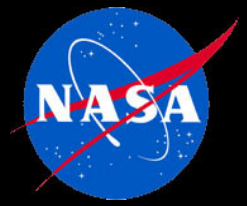


Risks of Being Good

- If you're the PI, people may think you are always right: so be careful! You are a single-point failure walking on Earth.
- Make sure your calculations are double-checked by somebody who doesn't know the right answer

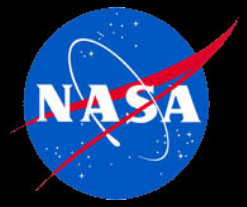
Major COBE Risks were social

- Concept: what if we forgot to think about a new effect due to cryogenics, noise, superfluid helium, spinning spacecraft, etc.?
  - Cold cables wouldn't flex
  - Aluminum distorted on cooling
  - Systematic errors hidden in noise, averaged for years
    - Magnetic susceptibility of RF switches
    - Electrical interference between computer clock, picked up by the ultrasensitive detectors
  - Light coming up from Antarctica stressed power system
  - Conclusion: PI or team inexperience is a major risk
- Test: what if we can't afford to test something?
  - Nature doesn't care if we can afford it or not
  - What if something breaks in test? We won't have resources to fix it, so why test?
  - After Challenger, Columbia, etc. we can confirm: management (including PI and customer) attitude is a major risk



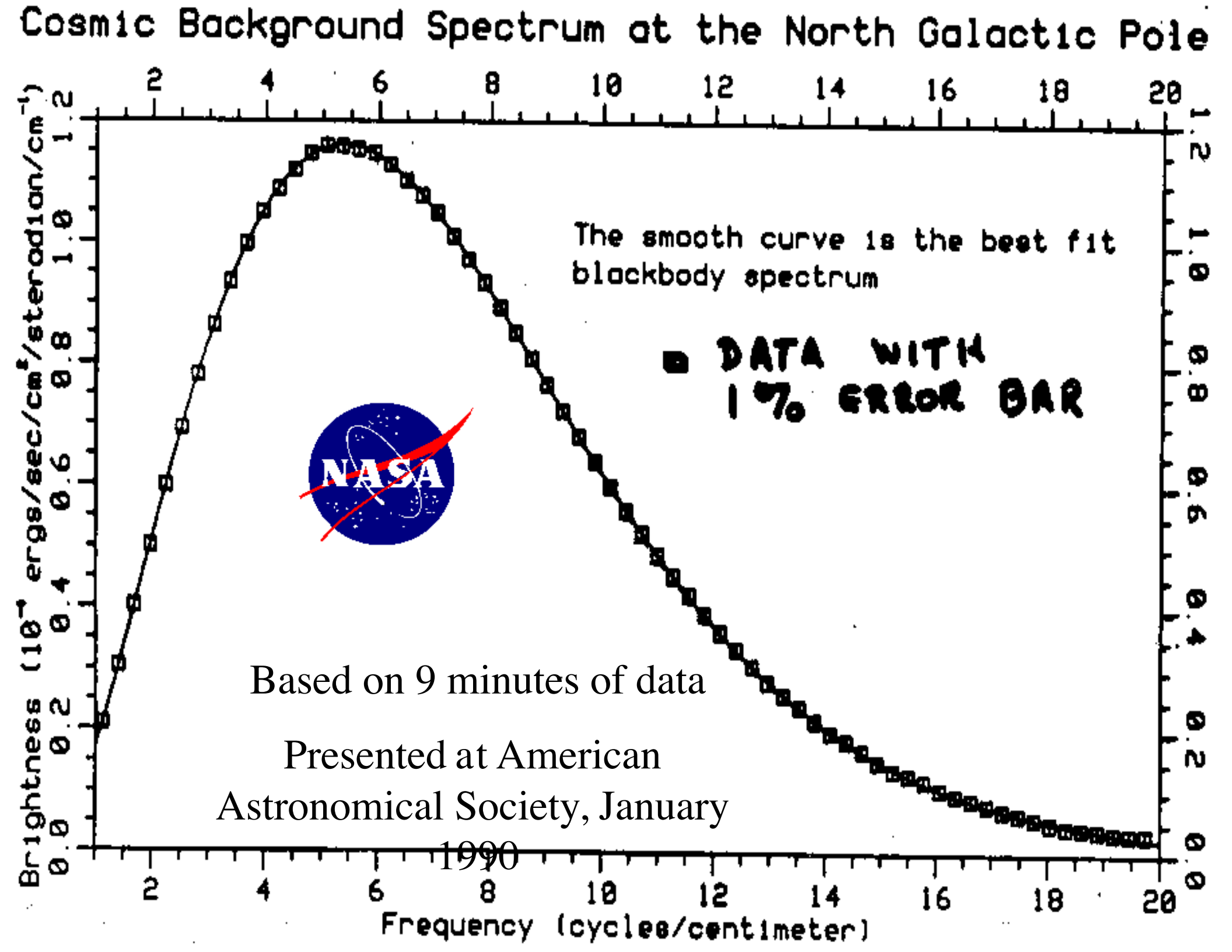
Some things are sure

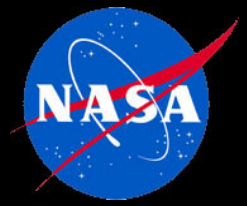
- People make errors
  - All 7 deadly sins, and many more
  - Biggest one: I thought I knew what I was doing (and other excuses), so I didn't tell anybody or complain or ask for help
- People find errors
  - Pure thought & document review
  - Peer review panels
  - Technology development (~ people development)
  - Test programs
  - Simulations
- People don't always find errors
  - Not enough time, money, imagination, all possible excuses
  - Your project is wrecking my other plans, so no you can't have any more time and money
  - Nature doesn't care about our excuses



Personal Risk Management

- I know 8 people who fell off a ladder or a roof
- I knew (of) several who died of too much exercise, including a quality assurance expert
- One was murdered
- One died young for no known cause
- Conclusion: can-do people are not programmed to appreciate L*C = Likelihood*Consequences
- Develop and use formal risk management process!!!

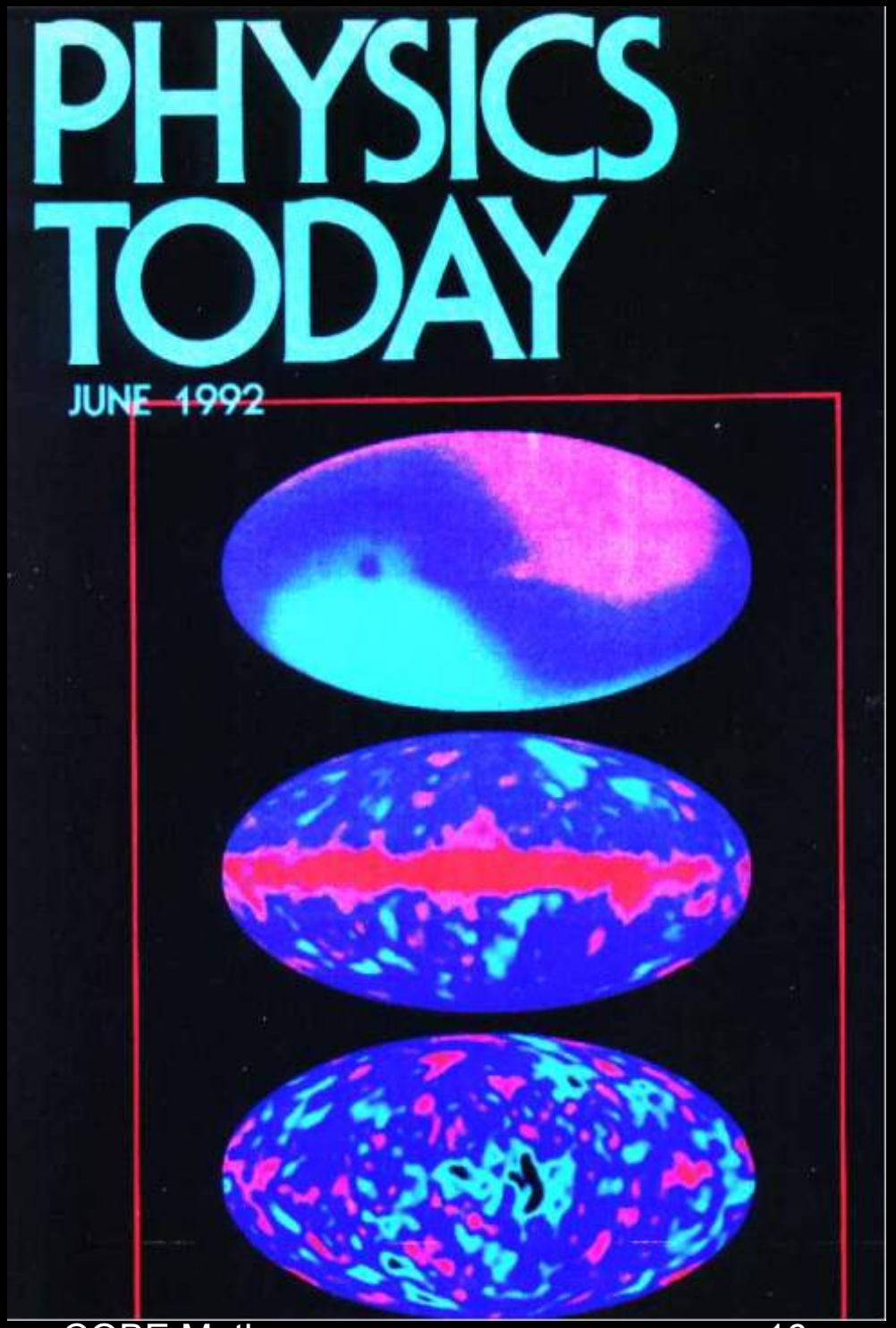

Cosmic Background Spectrum at the North Galactic Pole
The smooth curve is the best fit blackbody spectrum
DATA WITH 1% ERROR BAR
Based on 9 minutes of data
Presented at American Astronomical Society, January 1990
Brightness (10^{-4} ergs/sec/cm^2/steradian/cm^{-1})
Frequency (cycles/centimeter)

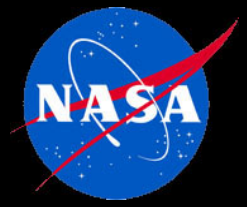


Sky map from DMR, 2.7 K +/- 0.003 K

Doppler Effect of Sun's motion removed (v/c = 0.001)

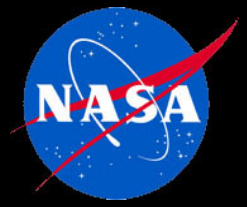
Cosmic temperature/density variations at 389,000 years, +/- 0.00003 K (part in 100,000)





Lessons from COBE

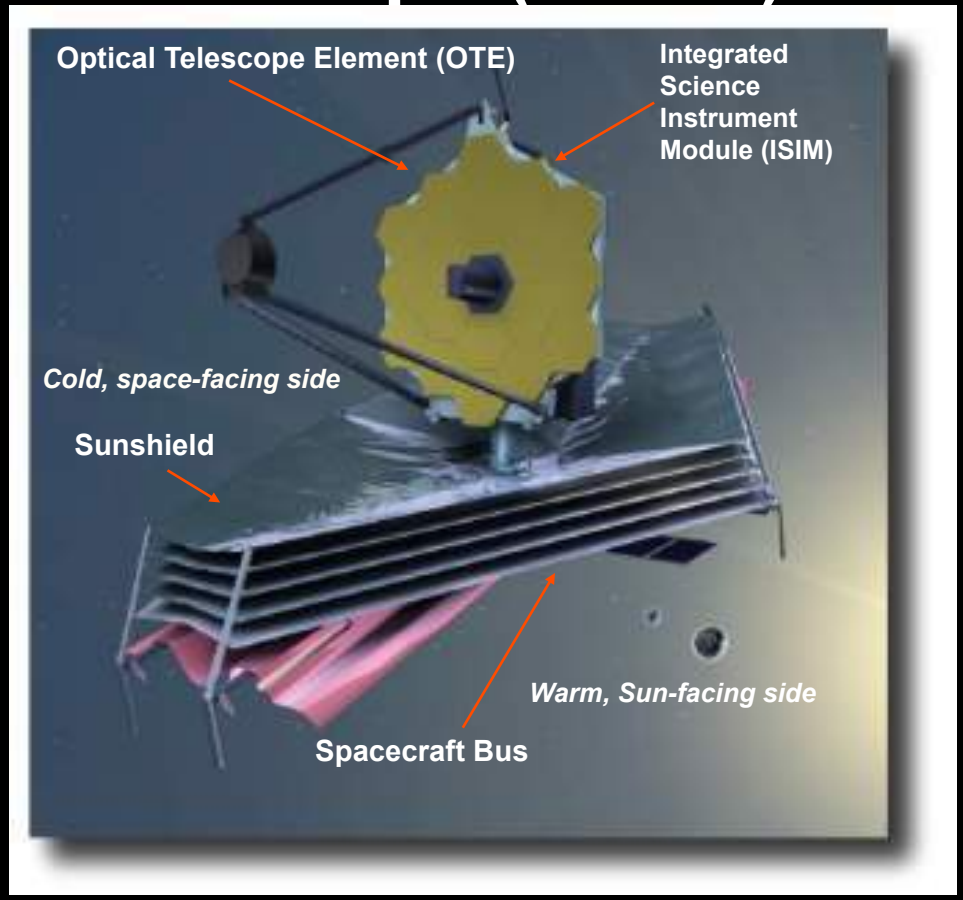
- Aim high - the world will change in 20 yrs.
- Do only what can't be done any other way
- If there's no law of nature against it, maybe it can be done: don't be intimidated
- If it's not forbidden, it's required: physics & astronomy
- Mather's Principle of Management: If it's not required, it's forbidden (but what *IS* required?)
- If it's not tested, it won't work: confidence ≠ success
- If it's tested, it won't work the first time either - plan to rehearse, test, rework, retest
- Elementary things fail: simple ≠ successful
- It's worth all this work: no substitute for major space missions



Summary & Implications

- Greatest risk is lack of imagination
  - See possibilities
  - Estimate likelihood
  - Appreciate consequence
- We're easily blinded by thinking about the resources we have
- Nature doesn't care what we think

James Webb Space Telescope (JWST)



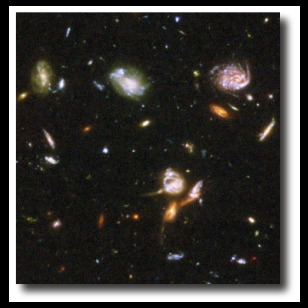
Organization

- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Space Technology
- Instruments:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - Fine Guidance Sensor (FGS) – CSA
- Operations: Space Telescope Science Institute

Description

- Deployable infrared telescope with 6.5 meter diameter segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch June 2013 on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)

JWST Science Themes



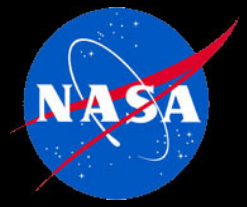
End of the dark ages: First light and reionization

The assembly of galaxies

Birth of stars and proto-planetary systems

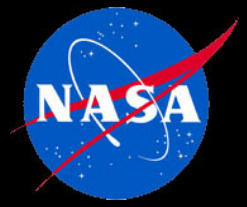
Planetary systems and the origin of life

www.JWST.nasa.gov



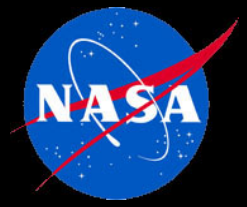
Choosing JWST Science & Scientists

- HST & Beyond report, 1995 draft, by Alan Dressler et al., recommended > 4 m aperture, near-IR optimized, with shorter and longer wavelengths if affordable
- Anticipated almost all scientific areas of current interest (exoplanets had just been found)



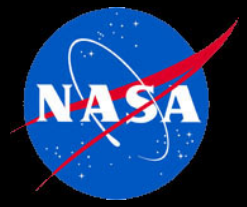
Series of 4 SWG's

- V-SWG, volunteers from GSFC, STScI, universities
- ASWG, Ad-Hoc Science Working Group, selected by HQ from proposals, defined instrument package and basic science, guided international partnership negotiations
- HQ sponsored instrument technology competitions, including detectors, micro-mirrors, microshutters, and ASICs
- HQ decided/negotiated that NIRCam would be US with Canadian participation, NIRSpec would be ESA, MIRI would be European Consortium with JPL, and Fine Guidance Sensor would be Canadian. All would use US detectors. GSFC won microshutter competition.
- ISWG, Interim Science Working Group, gave advice during competition phases
- Flight SWG (current), made up of ex officio scientists, 6 Interdisciplinary Scientists selected by HQ competition, and lead scientists for all instruments; chaired by Senior Project Scientist, chartered by Program Scientist (at HQ), advisory to Project Manager and Program Scientist



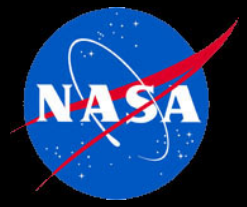
Science Assessment Team (SAT)

- External advice during descope discussion; more senior than SWG
- Recommended descoping requirement for short wavelength (< 1.7 μm) performance, but keeping short wavelength equipment
- Recommended relaxed contamination requirements, enabling different test program



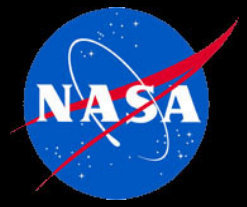
Other External Bodies

- National Academy of Sciences
  - Board on Physics and Astronomy
  - Space Studies Board
  - Committee on Astronomy and Astrophysics
  - Decadal Survey
- Similar European and Canadian bodies
- NASA working groups: Origins, SEU
- NASA Advisory Council (NAC), its Science Committee, Astrophysics Subcommittee
- STScI oversight boards: STIC
- Future: users' committees



Choosing Observers, like HST

- Most is General Observer time, based on proposals and review panels
- US selected observers get funds for analyzing data too - very popular
- Guaranteed time for instrument teams, ~ 800 hours/ team
- ~ 800 hours for 6 Interdisciplinary Scientists (combined)
- Percentage of Directors' Discretionary Time (was used for Hubble Deep Field, e.g.)
- No guaranteed time for ex officio team members - must write proposals



Dominant Science Themes

- First Light: first objects after Big Bang
- Assembly of Galaxies - from small parts?
- Formation of stars and planetary systems
- Evolution of planetary systems and conditions for life
- New things!!