



Starting a UV Mission Building from NGST Technology Strategy

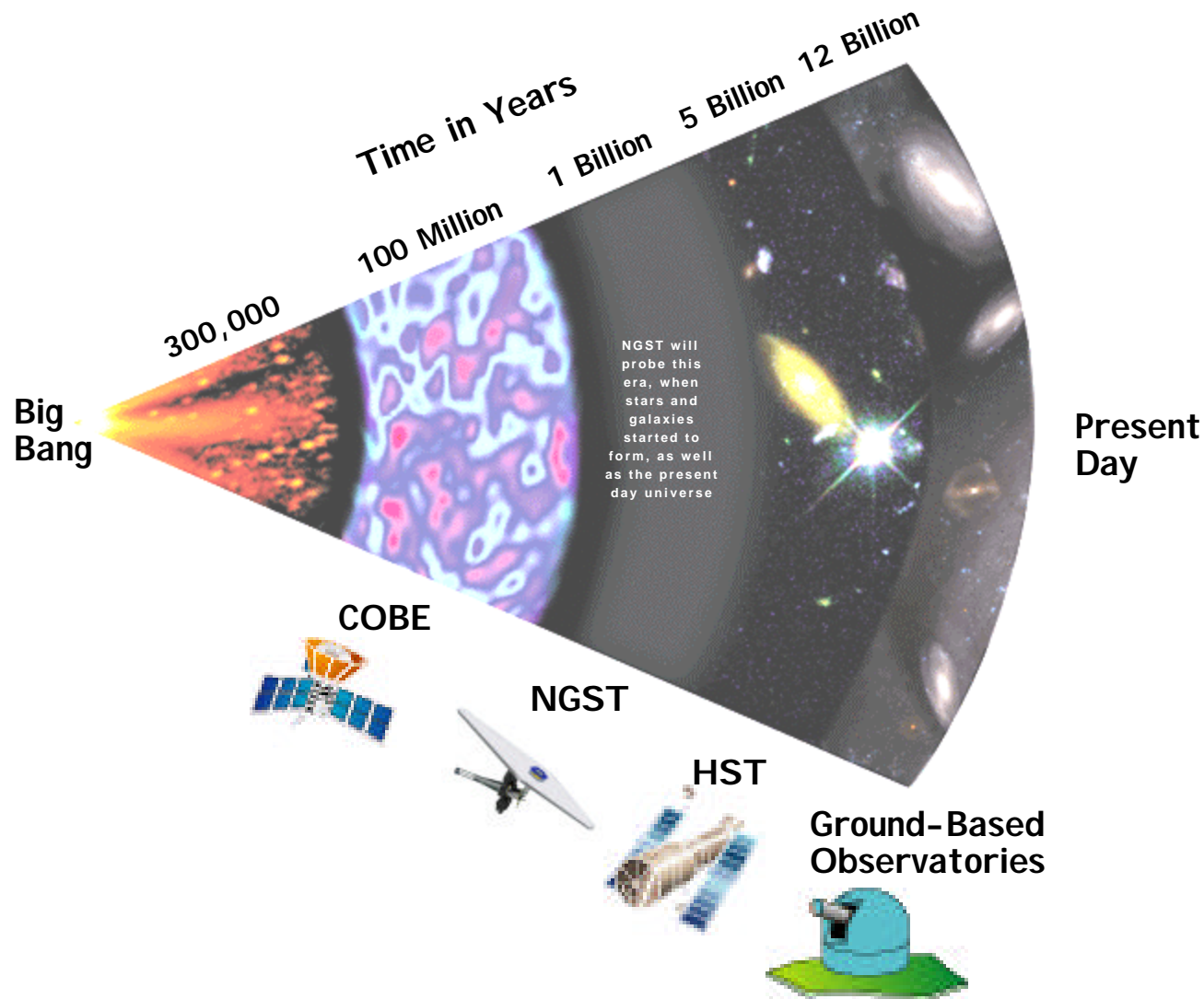
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NGST Sees the First Stars and Galaxies





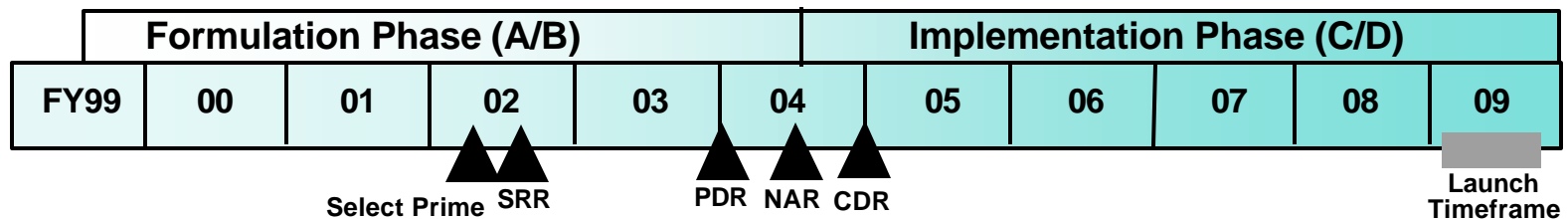
NGST Cryogenic Infrared Observatory at a Glance



- 6-7 meter diameter deployable primary mirror
- 0.6-28 μm wavelength range - near infrared optimized
- 5 year mission life (10 year goal)
- Passively cooled to <50K
- L2 orbit



- Number one mission in space astronomy per National Academy of Sciences
- Logical successor to HST
- Key part of the Origins Program – technologically as well as scientifically





Why wasn't NGST a UV telescope?



- Science priority from HST and Beyond committee
 - Interest in highly redshifted universe and planet formation
 - Huge infrared "discovery space" advantage over other equipment
- Difficulty of doing much better in UV-optical than HST and future ground telescopes with AO
 - UV detectors should be improved first
 - Larger mirrors with UV accuracy not currently feasible
 - Try an IR telescope first - sounds easier
 - Contamination control terrifying to many engineers



Hypothetical Design Objectives: UV NGST



- Diffraction limited imaging at $0.2\ \mu\text{m}$
- $50\ \text{m}^2$ aperture (8 m circle, or 4 x 16 m off-axis ellipse)
- Coronagraphic capability for planet searching and analysis, with extremely low stray light
- Huge field of view of telescope
- Huge detector arrays with extremely high efficiency
- Choice of spectrometers
 - High spectral resolution
 - Moderate resolution, highly multiplexed



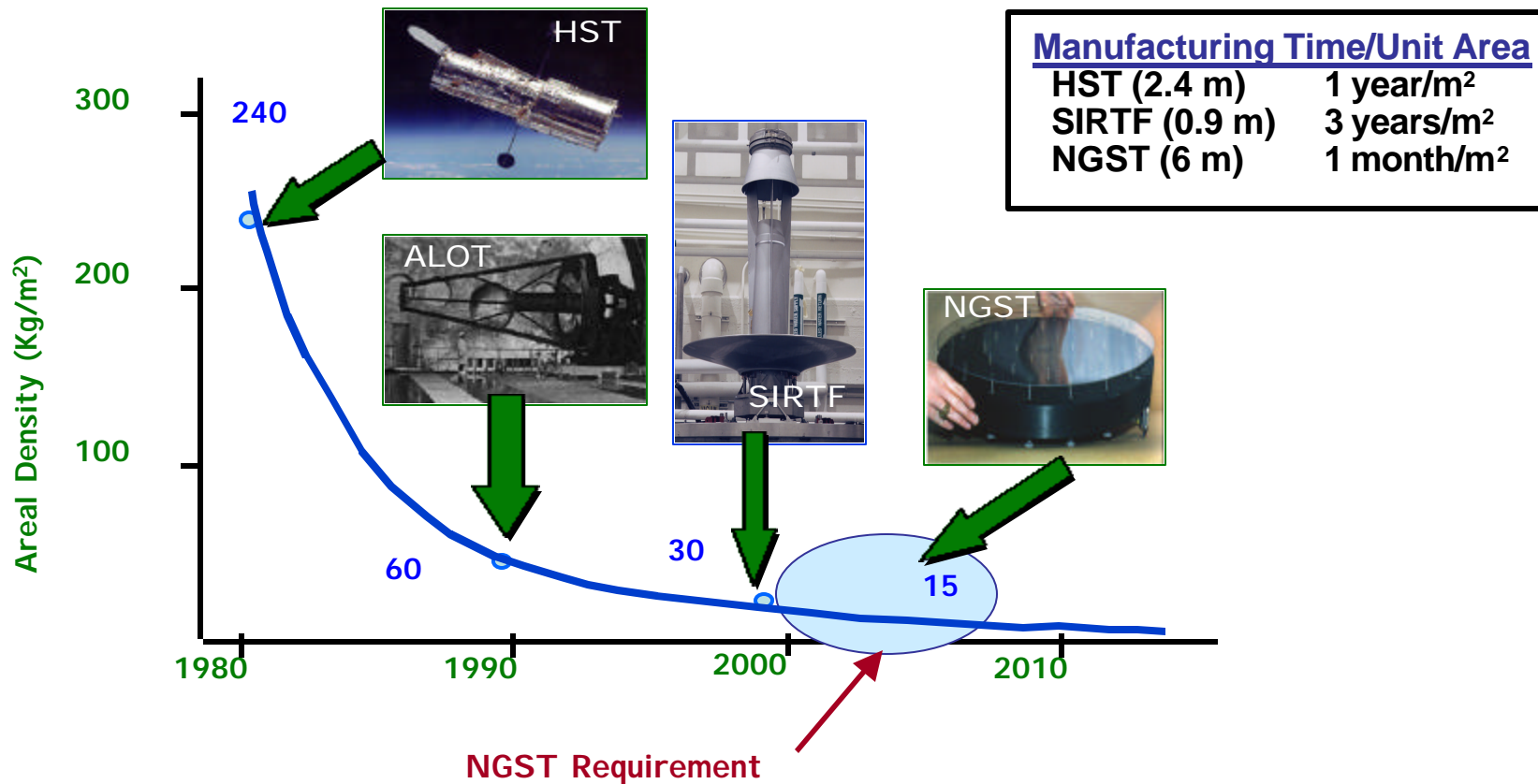
Mirror configurations considered for NGST



- Glass on glass (Kodak concept)
 - Traditional material, easily polished, several meters size possible
 - Sandwich for rigidity
 - Actuators for shape control on large scale
- Ribbed Glass on actuators (Goodrich concept) See Phil Stahl at MSFC!
 - Many actuators for medium scale shape control
- Ribbed glass bonded to carbon fiber ribs (Composite Optics Inc. concept)
 - Can match total thermal expansion at 2 temperatures (room and cold)
- Thin uniform glass on many actuators (U of Az concept)
 - Fragile, needs cheap lightweight reliable actuators
- Beryllium pieces, ~ 1.3 m size, individually rigid, with actuators for position and radius of curvature control; CTE not zero
- Silicon Carbide - near net shape molding processes



Mirror technology program demonstrates that NGST goals are within reach

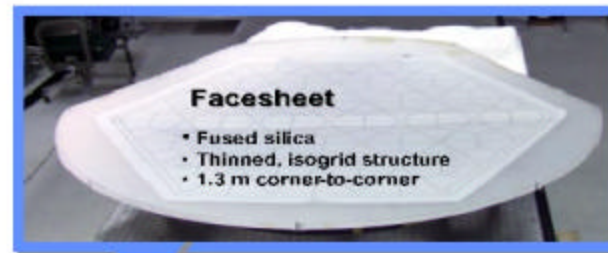
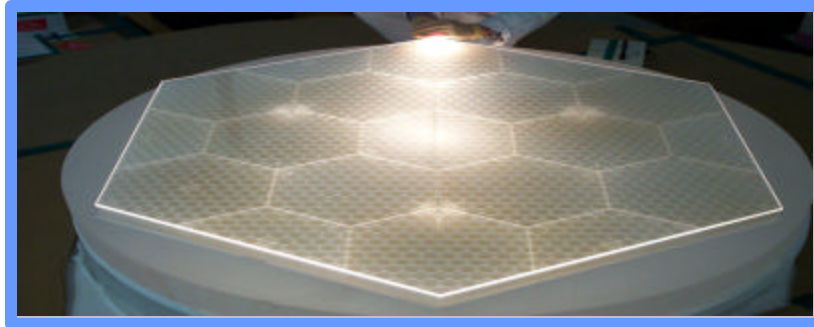
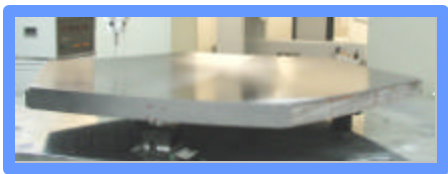
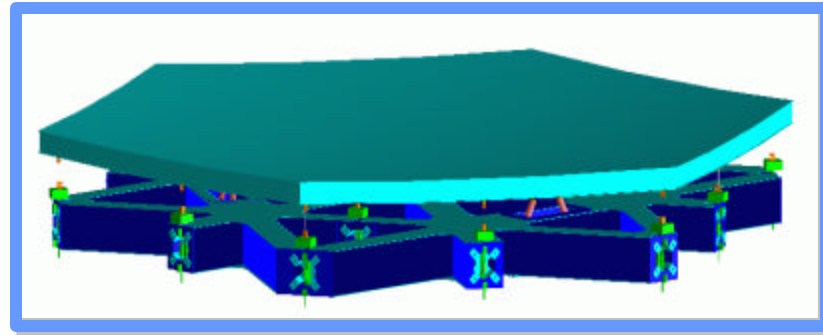




Mirror Technology Development Program



- NASA and DoD Partners have invested \$30M in mirror technology development:





Larger mirrors



- NGST aperture limited by polishing time and cost to about 6 m
- Further development requires time and investment, but there are many possibilities and NASA is not the only customer
- Competitions held by NGST were an excellent strategy - companies invested their own money and put good people on the job
- Conclusion: size not a real limiting factor in the 6 - 10 m range, no hard boundaries of the feasible
- Experience, money, mass, and packaging are limiting factors - let's do the homework



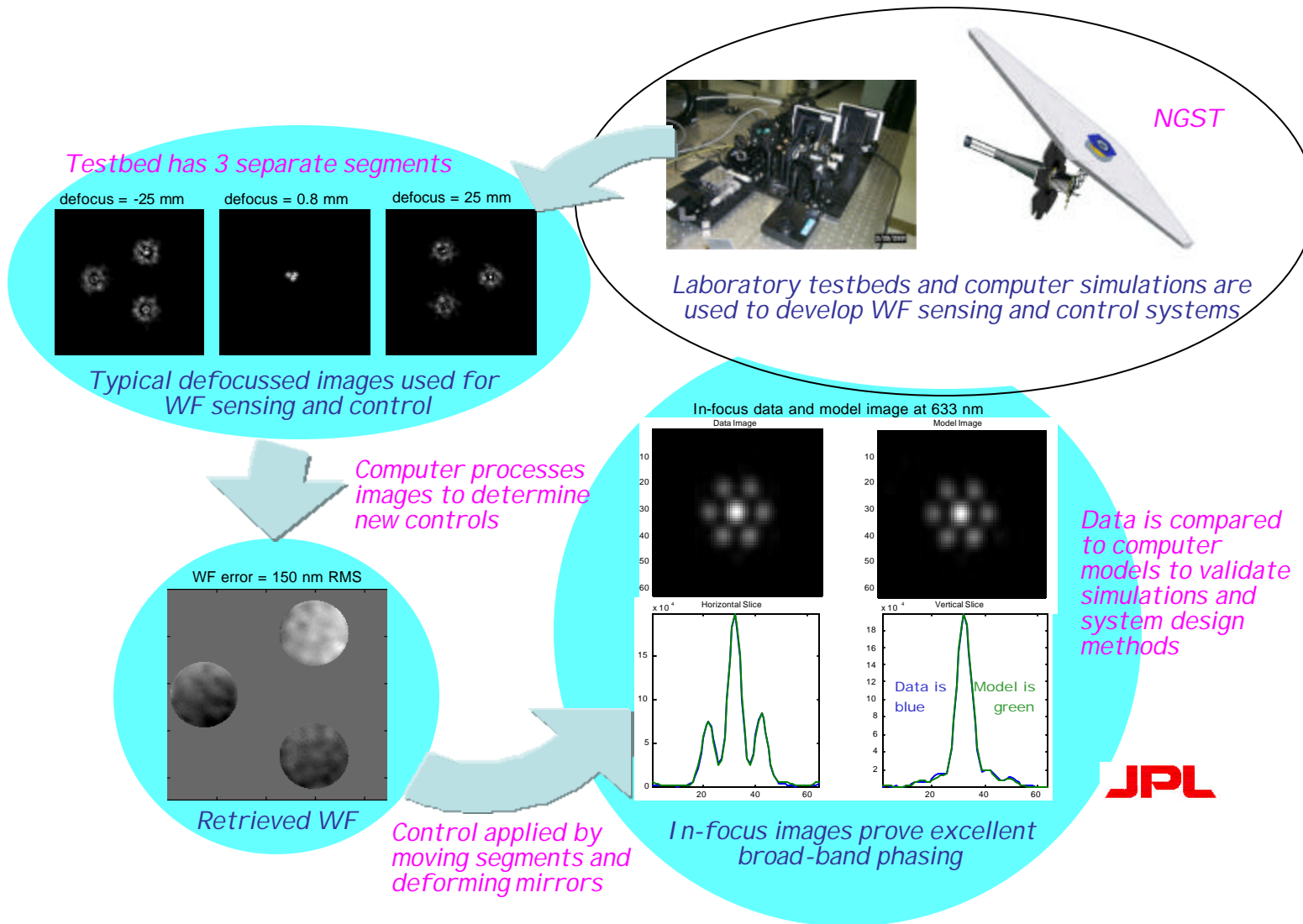
More accurate mirrors



- Need stability between fabrication and test to converge to desired shape
- Prefer to operate at same temperature as polishing step, as support ribs and structures print through on cooling
- Need low polishing force, deterministic polisher to avoid distortion and converge quickly
 - Vacuum laps, ion polishing, chemical polishing, mouse milk
- Allow for correction by high order small adaptive optical part at image of primary - studied by J. Trauger for NGST coronagraph
 - Much easier at room temperature - piezoelectric materials
 - Limited field of view if device is small and errors are large



NGST Wavefront Sensing and Control





Off-axis ellipse, monolithic mirror



- Launched standing on end in rocket shroud, proposed for NGST
- Asymmetric point spread function not popular with NGST science team
- Avoids discontinuities and gaps in mirror
- Simplified mirror figure control - continuity not an issue
- Unobscured telescope, far superior scattered light for coronagraph
- Secondary mirror tower need not be wimpy like NGST's
- Compatible with all NGST mirror technologies - can join smaller segments before polishing to final surface



Contamination control



- A serious cost challenge if not approached right
- Major hazard: polymerization of hydrocarbons by solar UV
- Solution approach:
 - Build it clean, bake it out, bag it until launch, maybe even inside rocket shroud
 - Keep mirror warm compared with condensation temperature of organic vapors
 - Don't deploy in sunshine or in Earth albedo - need aperture cover?
 - Go to deep space orbit to avoid Earth albedo
 - Keep the astronauts (if any) and Shuttle very clean, or don't use them
- Risk reduction approaches
 - Develop on-orbit cleaning with ion beams or liquid CO₂ (shuttle test)
 - Develop on-orbit recoating (but only works for one or two surfaces)



Mirror coatings



- Coatings limit short wavelength coverage
- Does the science drive us to bare metal applied in space?
- Is there progress to be made?



Better pointing



- NGST and HST have same stability requirements, but future UV telescope must do better
 - Finer pointing than HST, but more photons from guide star, should be easier
- NGST has much relaxed absolute pointing - no astrometry needed
- NGST is in a quiet orbit: no outside disturbances
- To achieve stability, need:
 - Low internal vibration - e.g. active and passive isolators for momentum wheels, and active and passive isolators between spacecraft bus and telescope
 - Fine star tracker - limited by photon statistics and numbers of stars, must see about 16th magnitude to get 4 per FOV



Configuration issues - orbit



- Low Earth orbit (Space Station) - build like HST, penalties for Earth - Sun geometry, Earth albedo an issue, but servicing possible
- Low Earth polar orbit (COBE) - much more stable thermal environment, avoids Earth eclipse much of year (depending on altitude) - servicing not currently feasible, but may be in future
- High Earth orbit - (IUE, ISO) - thermally stable, avoids most albedo, return or servicing relatively easy, but takes more rocket energy than Station orbit
- Deep Space orbit (NGST, MAP, Planck, Herschel, SIRTF) - thermally stable, much harder to retrieve or service; data rate adequate with L2 orbit or higher gain antenna (SIRTF)

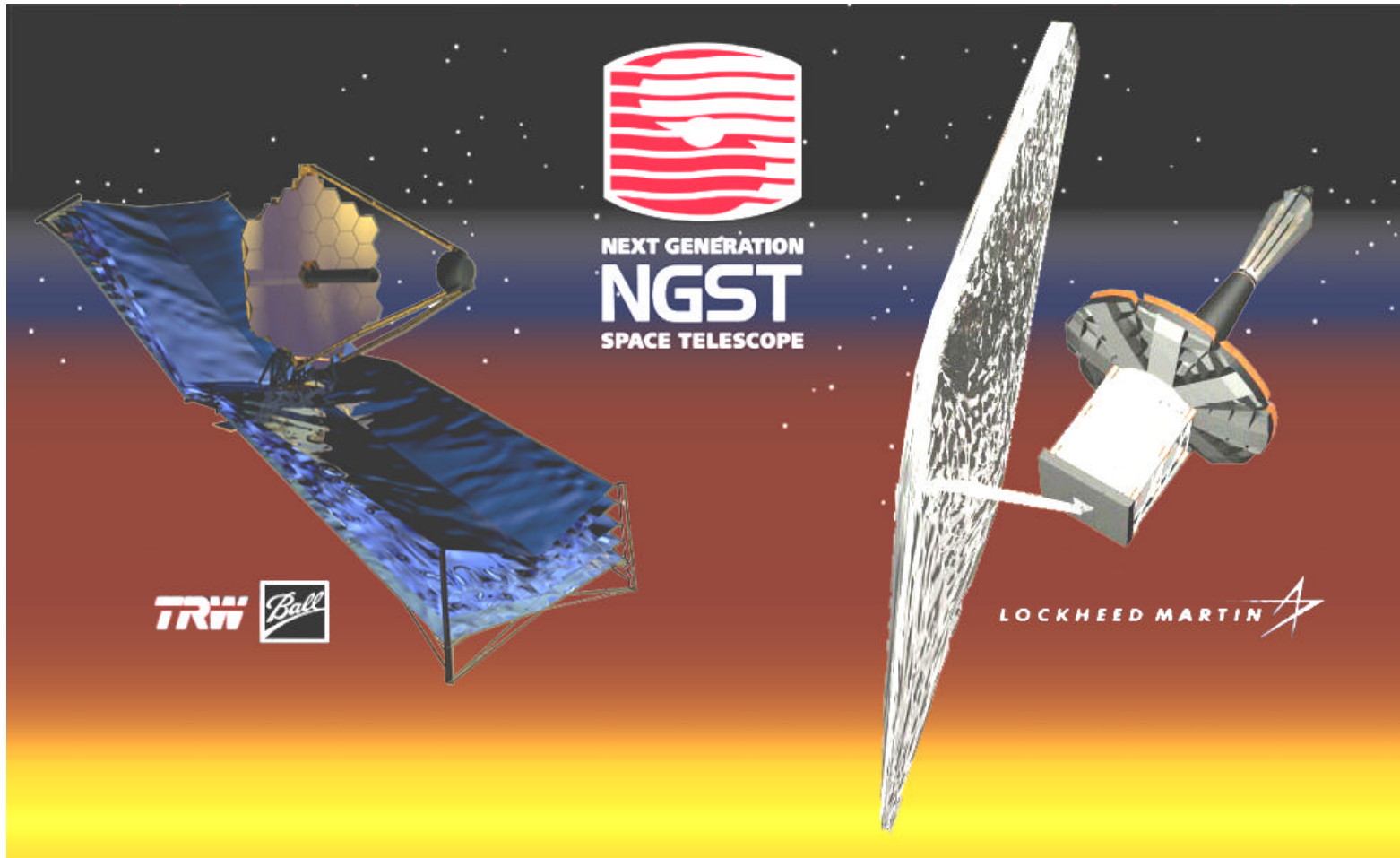


Configuration issues - Tube or Naked?



- NGST mirror will get ~ 0.2% pits from micrometeoroids in 10 years
- NGST will be cold - can't stay warm looking at deep space behind a shield
- To keep primary mirror warm, need a tube, or lots of heat
 - 50 m² at 300 K and 0.05 emissivity radiates 1250 W (readily available with heat pipes or electrically)
- To control thermal gradients, need a tube or lots of local temperature controllers or very high passive conductance
- To achieve stability, need independence from orientation with respect to Sun
- Solar flux changes 7% pk-pk over 1 year
- Baffle tube could be deployed by inflation of plastic film with included, or erected like NGST with arms and cables

Comprehensive and Systematic Trade Studies Have Produced Two Viable Observatory Designs





Configuration issues - servicing



- Only currently available servicing capability is with Shuttle at low altitude
- Forecast: expect rapid progress in tele-operation of robotics
 - Defense
 - Surgery
 - Inspection and repairs of pipes - e.g. N Y City water supply
 - Hazardous materials handling - chemical, biological, nuclear
 - Space station assembly robots
 - Underwater
 - Mining
 - Farming
 - Inventory management



Special Telescope Assembly Robotics



- NGST assembly robot concept developed by R. Muller
- Central hub, 2 arms, each with manipulators, grabbers, and electrical connections
- Robot can walk around spacecraft attaching to footholds and doing work
- Redundant robots for reliability
- Allows more efficient use of rocket shroud volume
- Robotic servicing at L2 possible
- Robots can be clean and even cryogenic
- Can avoid need for astronaut-safe hardware



Benefits of Remote/Robotic Assembly



- Larger instruments, more efficiently packed
- Wide range of possible configurations, not limited to simple hinges
- Can stow optics in contamination protection chambers
- Flexible response to failure, if spare parts carried, or provided on servicing mission
- Flexible adjustment and configuration of future very complex systems, e.g. interferometers
- Robots can be contamination-free and can reach cryogenically cooled regions
- Robots can operate near delicate optics, because they don't get tired or impatient, and can follow pre-programmed sequences



10 Meter NGST Stowed in Atlas Large Fairing

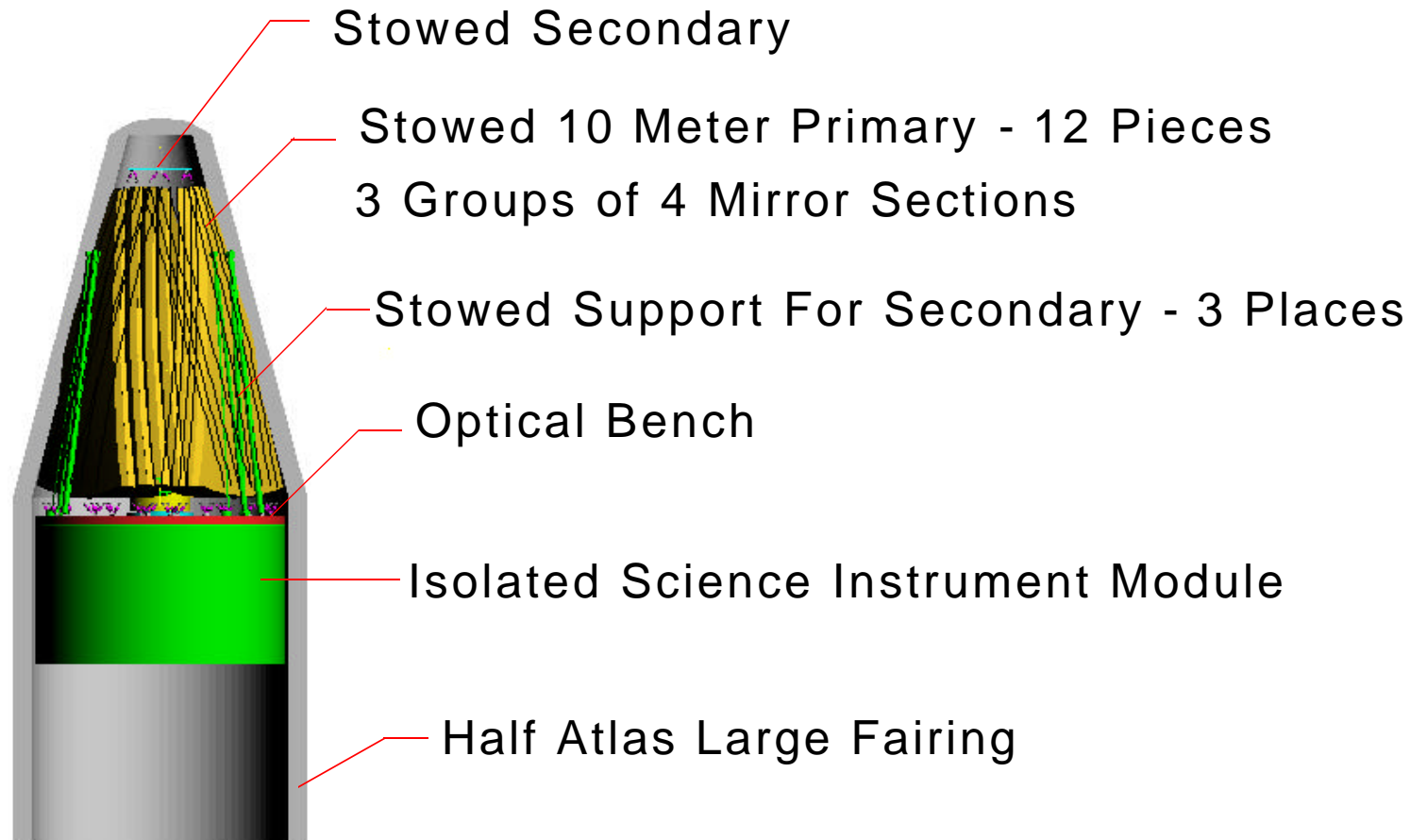




Figure 1 - 20-Meter Telescope Stowed in Delta IV Shroud

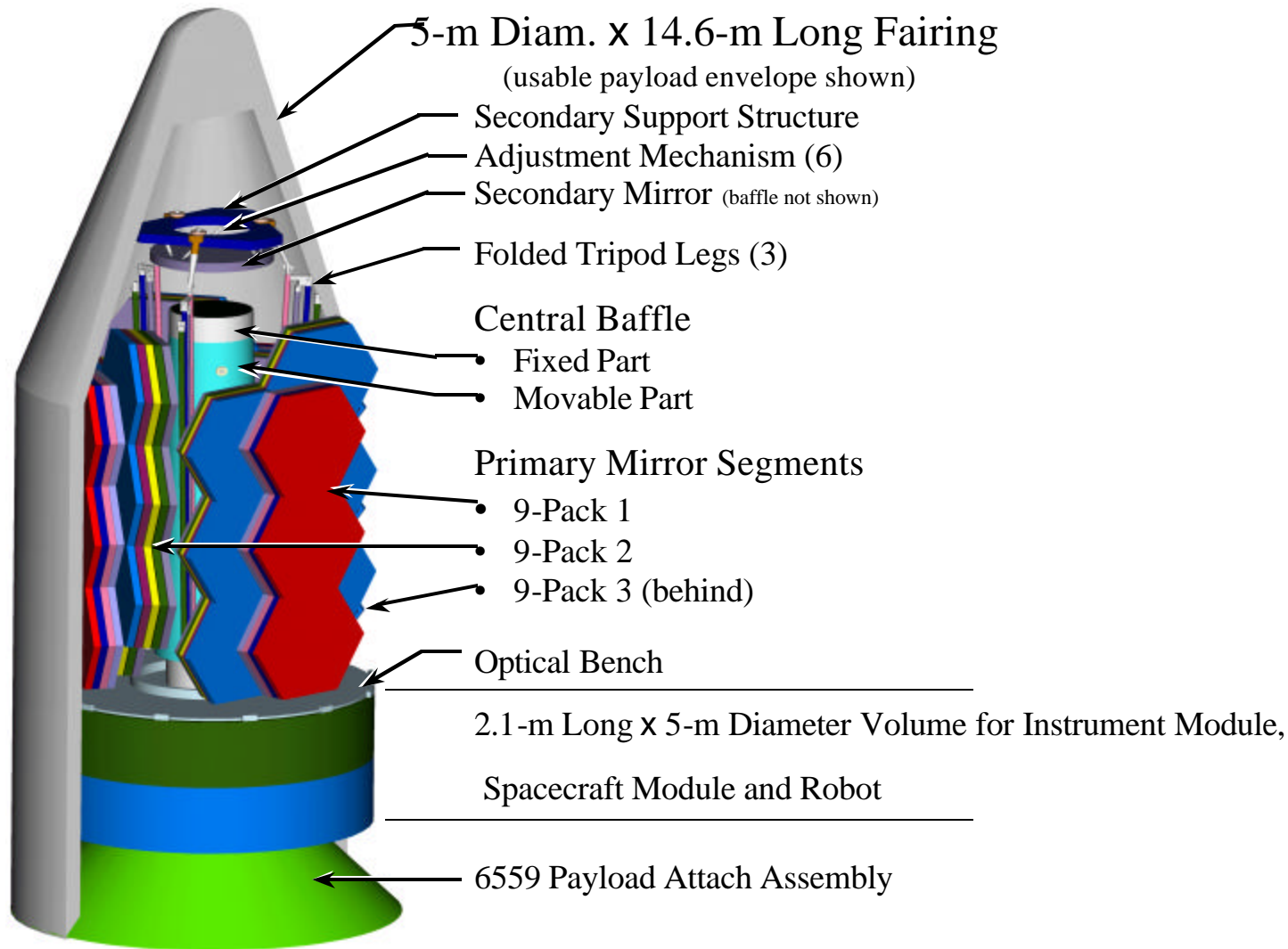




Figure 3A - Spar 6-Meter Robot

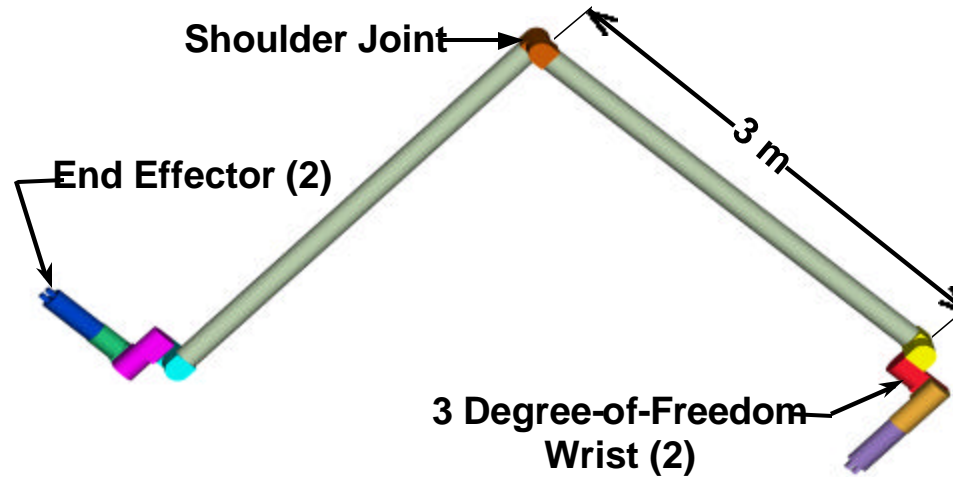
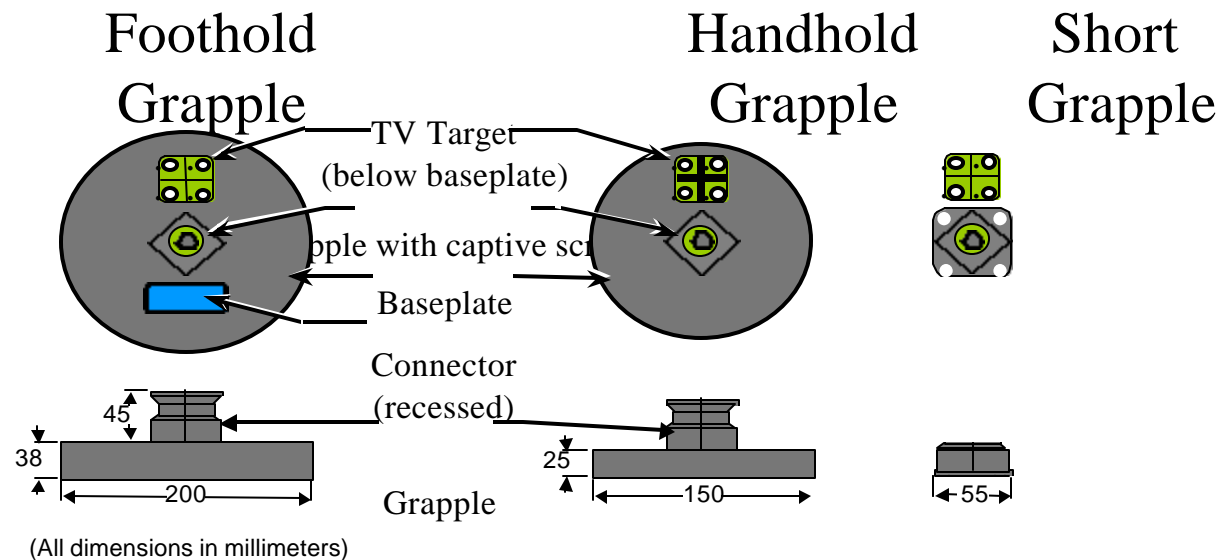


Figure 3B - Grapple Configurations





Better detectors



- Detector requirements drive the mission configuration - are they cold? Do they need a cold telescope? Do they provide energy resolution? What kind of electronics do they need? What data rate do they produce? Do they inspire new scientific goals?
- Detector investments can have very high benefit per unit cost, much more than mirror area, e.g, but need tens of \$M to make progress - Hold competitions with real money and real payoff in flight data
- Moore's law works, but only if there's strong demand and reward for progress
 - Doubling time for I R detector speed over past 50 years is even faster than 18 months
 - Let's have a new shot at the UV!



Instrument technology



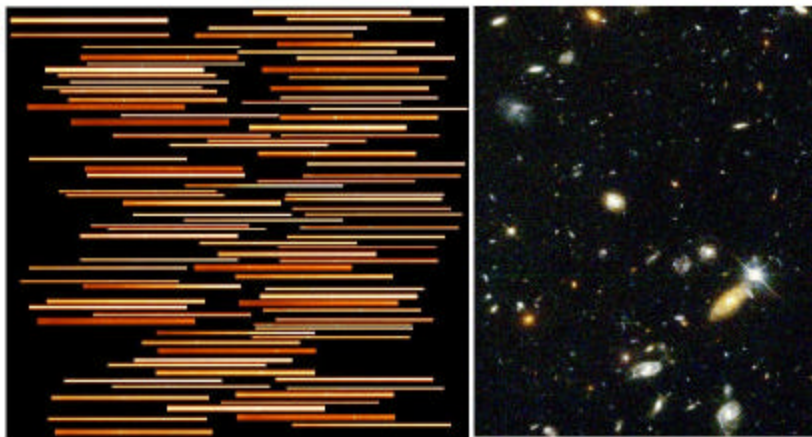
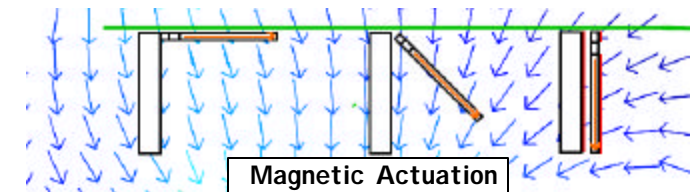
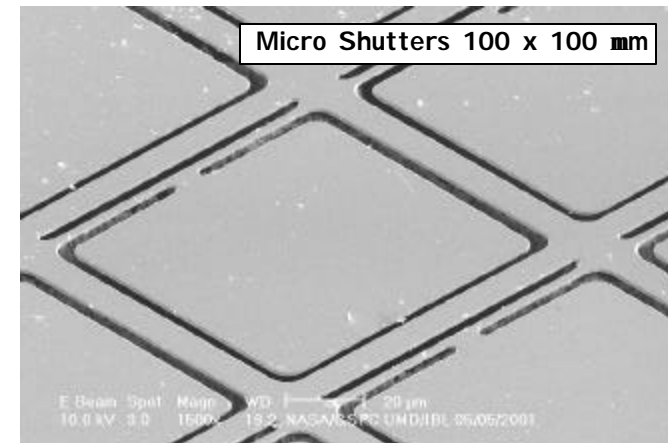
- Coronagraphs:
 - Rotation shearing interferometer - suppresses on-axis radiation, good for looking close to star
 - Lyot stops with wavefront corrector - J. Trauger for NGST
 - Can cope with segmented primary, at penalty in performance
 - Special apodizing masks
 - Circular graded near-Gaussian transmission
 - Square version of near-Gaussian mask
 - Shaped aperture (binary) mask
- Multiplexed spectroscopy - can use NGST concept of microshutters and gratings



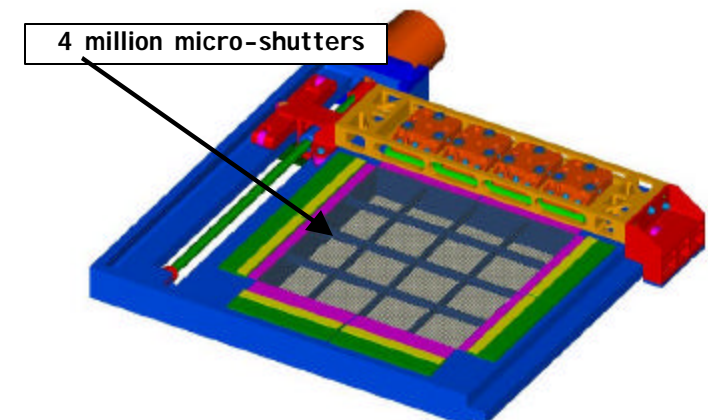
GSFC MEMS Programmable Aperture Mask for NGST Multi-Object Spectroscopy



- Enables first orbital multi-object spectrometer
- Simultaneous spectra of up to 1000 targets per exposure
- Key capability for discovery of the first stars and galaxies
 - must observe many targets to find these rare fossil remnants of the early universe
- Fusion of NASA and DoD technologies
 - Magnetic Film technology provided by Naval Research Lab



Multi-Object Spectroscopy Simulation





Conclusions and Recommendations



- Be ambitious: the time frame is long and the competition (for funds and scientific discoveries) is strong
- Be poetic: scientific goals must be as inspiring as the technical challenges are difficult to meet them
- Start with the top payoff items: detector development
- **HELP FINISH NGST - APPLY FOR THE OBSERVATORY PROJECT SCIENTIST POSITION!!**