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__Mission Objective (Easton):__ Produce high spatial resolution (< 2 cm geoid error at 50 - 100 km wavelength) models for mean and time variable (<15 days) components of global Earth gravity field with unprecedented accuracy for a period of at least 5 years.

- **Mapping of the Earth's gravity field from space offers global, continuous and homogeneous high quality monitoring of the static and time variable components of the Earth's gravity field. Areas of significant impact:**
  - ***Oceanography*** **- measurement of time varying ocean bottom pressure, deep currents, removal of mean geoid at cm level to ~100 km or better (sub mm at longer wavelengths)**
  - ***Hydrology*** **- monitoring groundwater, deep soil moisture, and aquifers at the cm level to ~100 km or better (mm at longer wavelengths)**
  - ***Glaciology*** **- monitor changes in polar ice caps at cm level to ~100 km or better**
  - ***Solid Earth Sciences and Geodesy*** **- measure lithospheric thickness, mantle viscosity, improve navigation and orbit determination of LEO spacecraft.**

- **Team: M. Watkins (Lead), B. Tapley (representing 10+ GRACE science team members), W. Folkner (technology), B. Chao (GSFC)**
- **HQ Contact: Clark Wilson**

Mission Overview

- Two coplanar spacecraft in circular, polar, orbits at 600-800 km altitude
- Distance between s/c measured with advanced laser inteferometry. Periodic maneuvers to maintain separation loosely to 50-200 km. Ground track repeat controlled to within ±5 km.
- Lifetime: 5 year baseline, 10 yr goal

Spacecraft

- Small sats (2), ~150-200 kg, ~100W including thermal control, ACS, etc.
- Optional low thrust drag compensation system (takes output of inertial sensor and thrusts accordingly): 40 kg, 25W

Instrument

- Laser interferometer (measure satellite separation to ~100 pm): 10W, <100 Mb/day, 1 microrad pointing relative to other s/c.
- Inertial sensor - to measure drag forces: 10W, <1 Mb/day

Baseline Mission

- Frequency stabilized laser dual satellite interferometer
- 2 satellites likely derived from GRACE design
- "standard" inertial sensor + direct ranging to proof mass

=> Performance 0-1 order of magnitude better than GRACE from 10000 - 1000 km,
2-3 orders of magnitude better from 1000 - 100 km.

Improved Science Mission

- Frequency stabilized laser dual satellite interferometer
- 2 satellites likely derived from GRACE design
- "Improved" inertial sensor + direct ranging to proof mass
- Drag-free propulsion using proportional electric thrusters

=> Performance 3-4 orders of magnitude better than GRACE at long wavelength,
2-3 better at short wavelength

Mission Ops/Satellite Comm:

- **Very simple - 1 S-band up/downlink stations (e.g. Wallops 5m), < 100 Mbytes/day**
- **Cost ~ $1M/yr**

Science Data Processing

- **Similar to GRACE, 1-2 processing centers for gravity field generation (Level 1-2 products) (computationally intensive).**
- **Science Team for higher level products and interpretation**
- **Archive - relatively small data volume, easily accomodated at any DAAC, DIS, etc. Could continue with JPL PODAAC as with GRACE**

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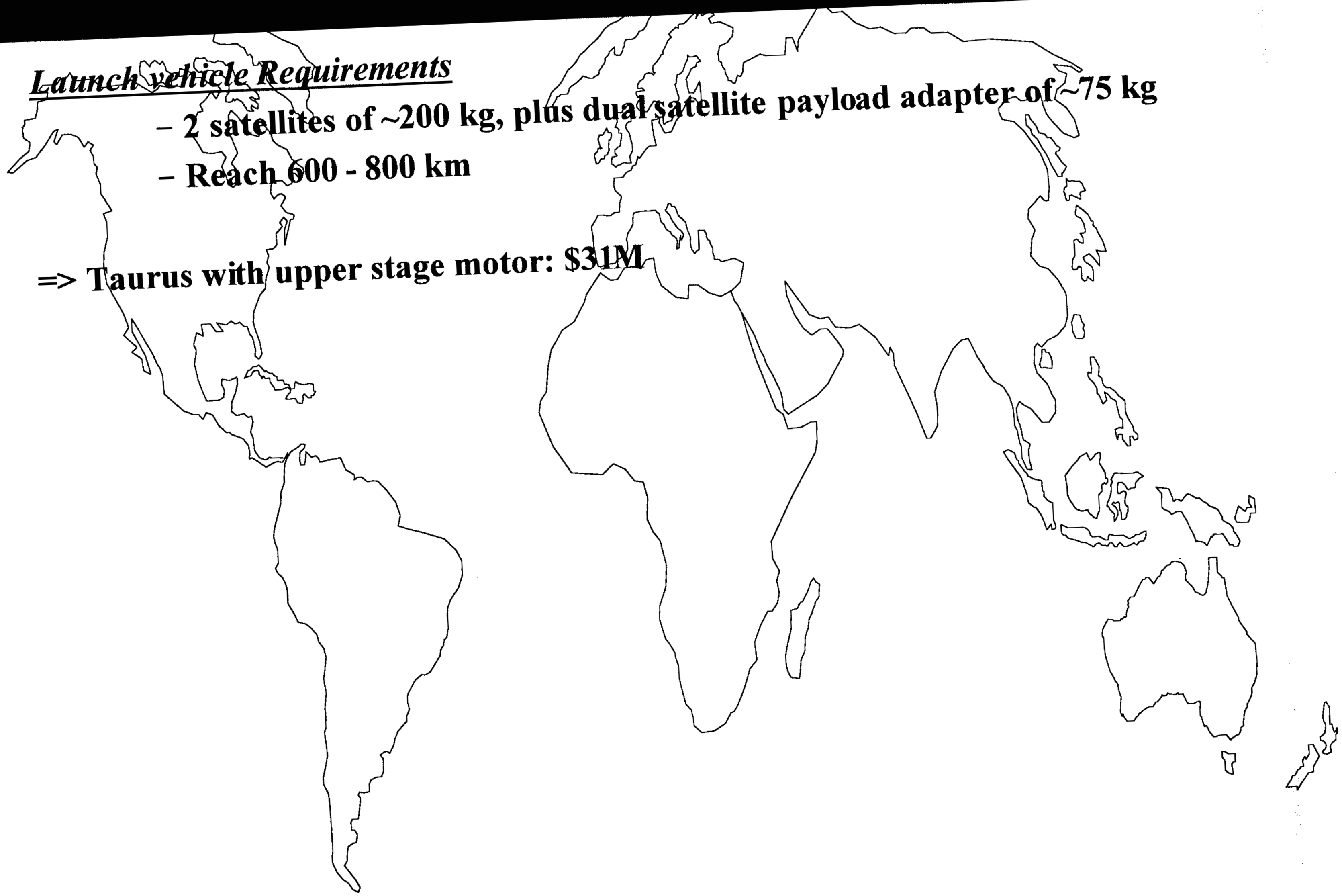


Launch vehicle Requirements

– 2 satellites of ~200 kg, plus dual satellite payload adapter of ~75 kg

– Reach 600 - 800 km

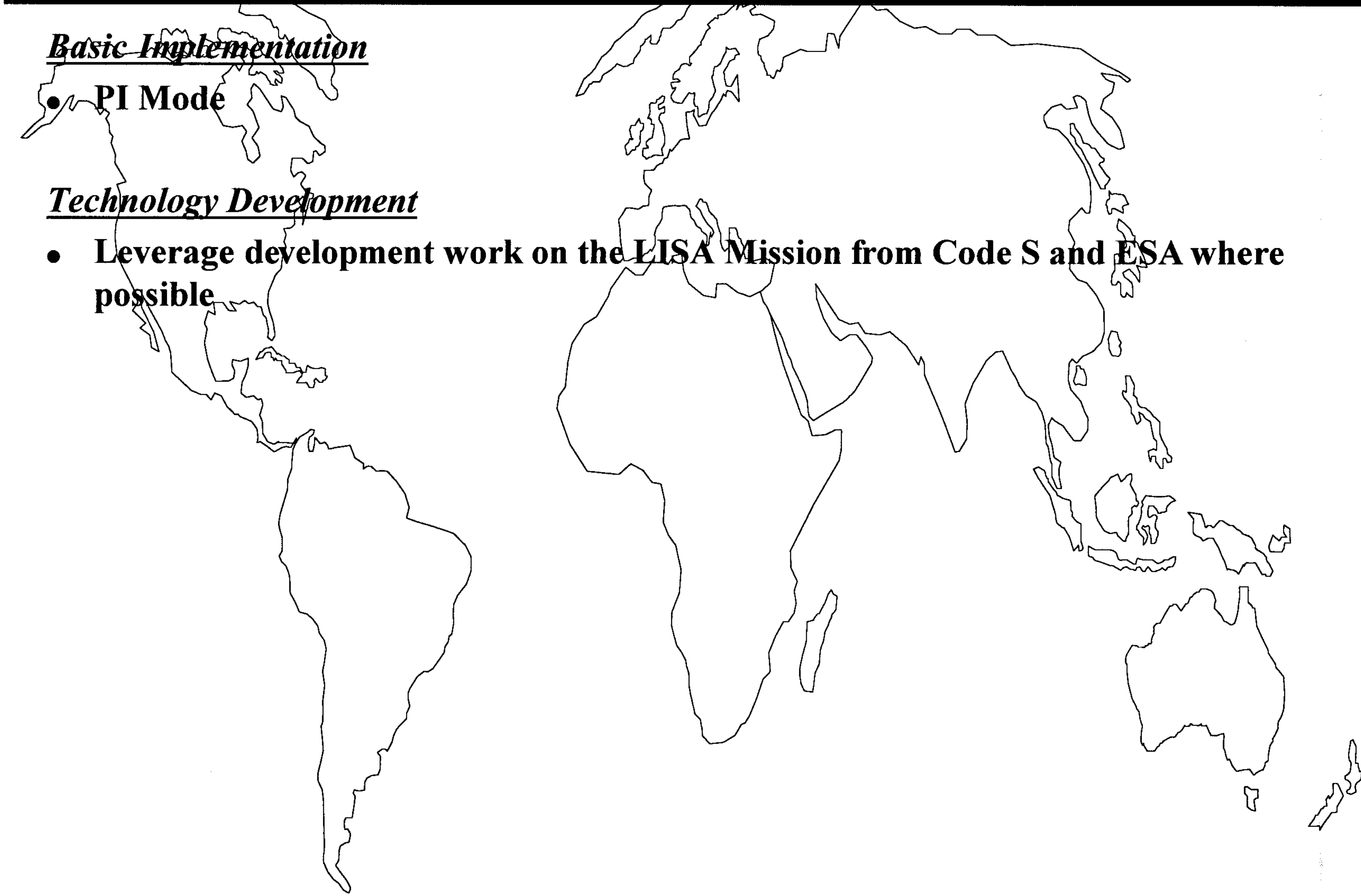
=> Taurus with upper stage motor: $31M

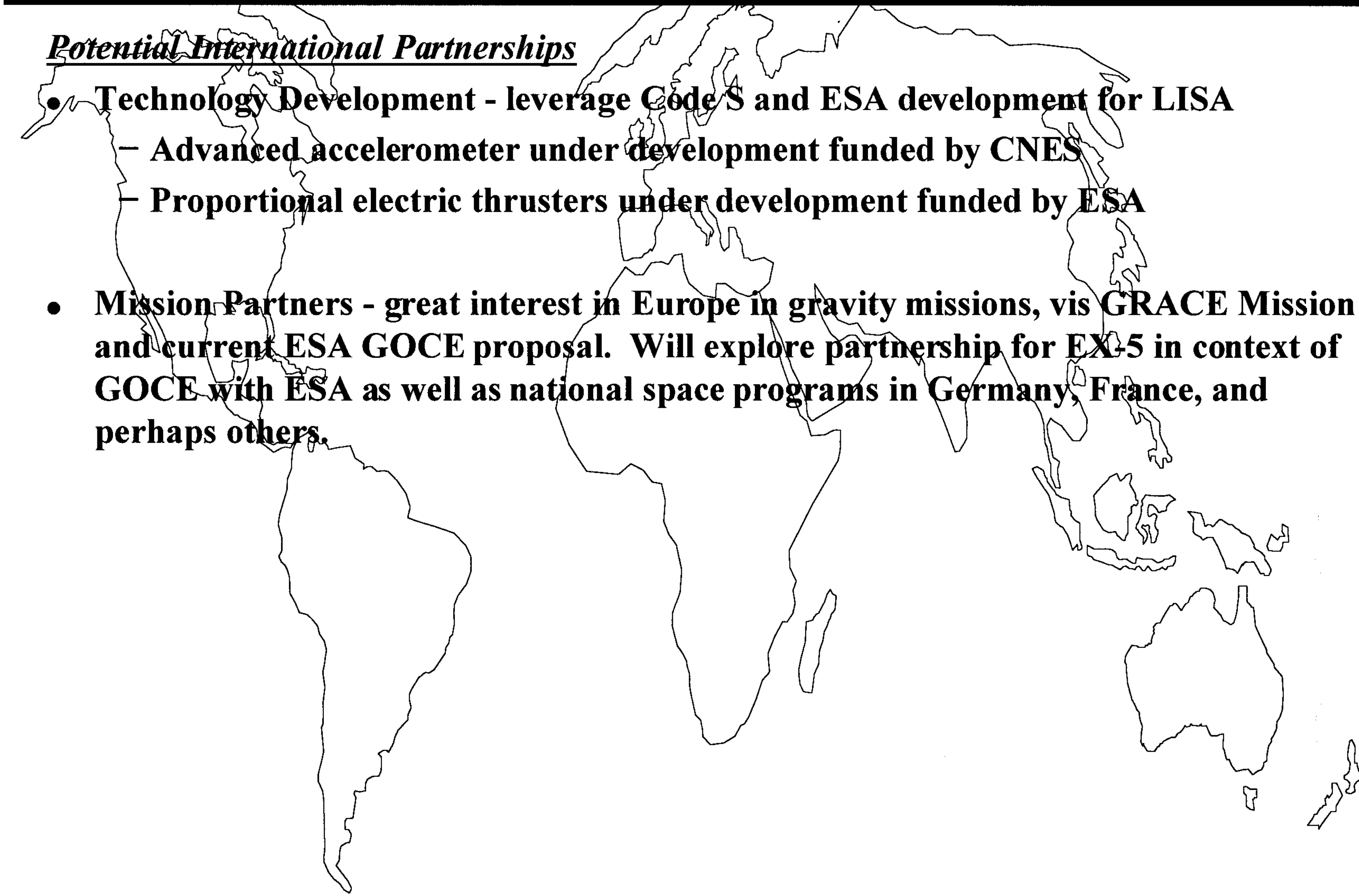
Basic Implementation

- **PI Mode**

Technology Development

- **Leverage development work on the LISA Mission from Code S and ESA where possible**

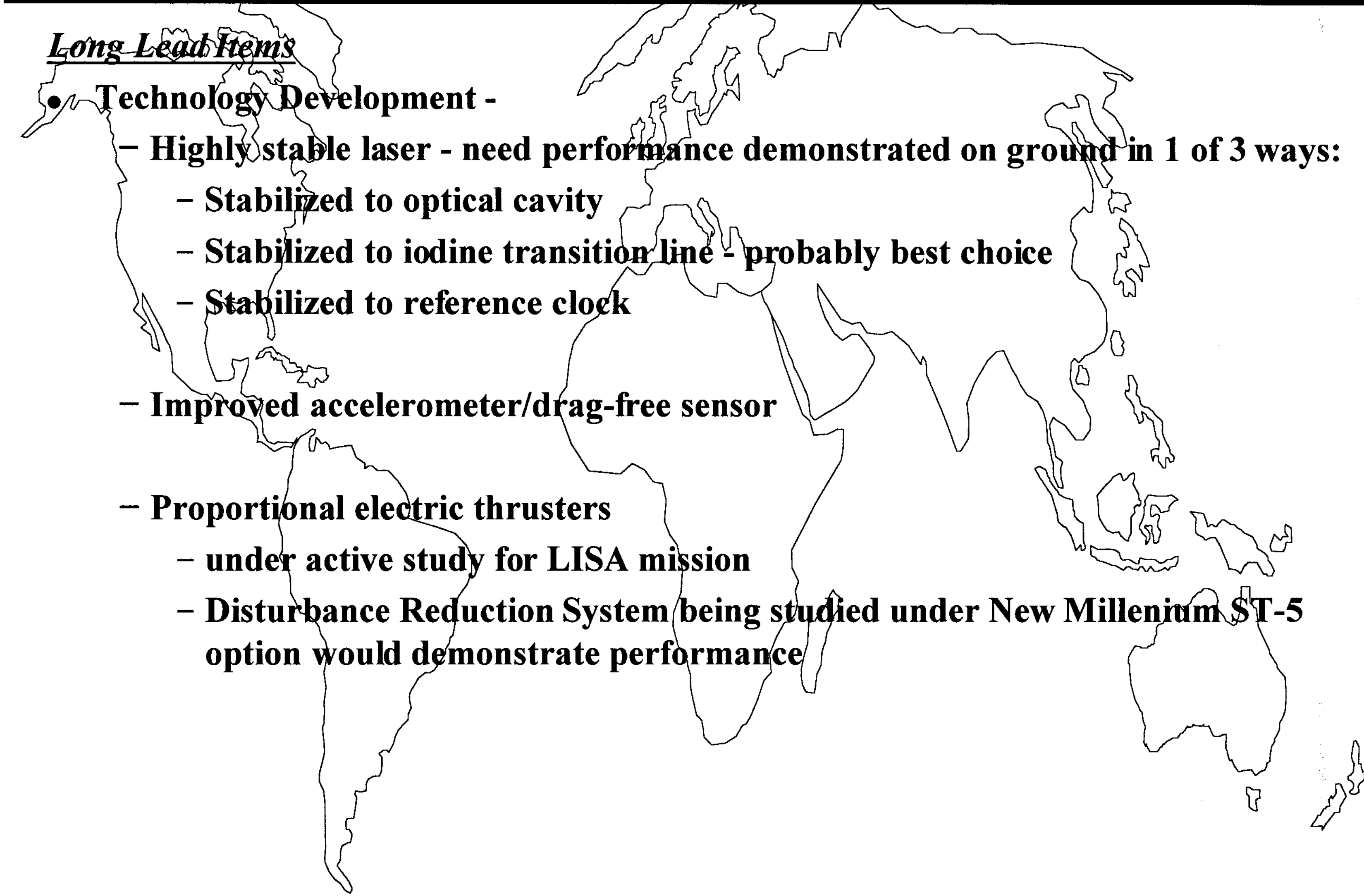




Potential International Partnerships

- **Technology Development - leverage Code S and ESA development for LISA**
  - **Advanced accelerometer under development funded by CNES**
  - **Proportional electric thrusters under development funded by ESA**

- **Mission Partners - great interest in Europe in gravity missions, vis GRACE Mission and current ESA GOCE proposal. Will explore partnership for EX-5 in context of GOCE with ESA as well as national space programs in Germany, France, and perhaps others.**



Long Lead Items

- Technology Development -
  - Highly stable laser - need performance demonstrated on ground in 1 of 3 ways:
    - Stabilized to optical cavity
    - Stabilized to iodine transition line - probably best choice
    - Stabilized to reference clock
  - Improved accelerometer/drag-free sensor
  - Proportional electric thrusters
    - under active study for LISA mission
    - Disturbance Reduction System being studied under New Millenium ST-5 option would demonstrate performance

Qualitative Assessment of Risks

- **Technical:**

  Baseline option - ***Low*****, uses heritage from GRACE + modest development. Instrument is in many ways more robust than GRACE, eliminating multipath issues, analog RF component problems, and the center-of-mass trim subsystem.**

  Improved option - ***Low-Med,*** **needs additional tech development on drag-free system and improved inertial sensor. Has same reliability benefits as above, but would also enable much easier science processing, provide easy way to maintain ground track repeat.**

- **Programmatic:**

  Low -Med- **contributions from the LISA program for tech development would be of value to the mission. Without them, tech dev. costs will be higher.**

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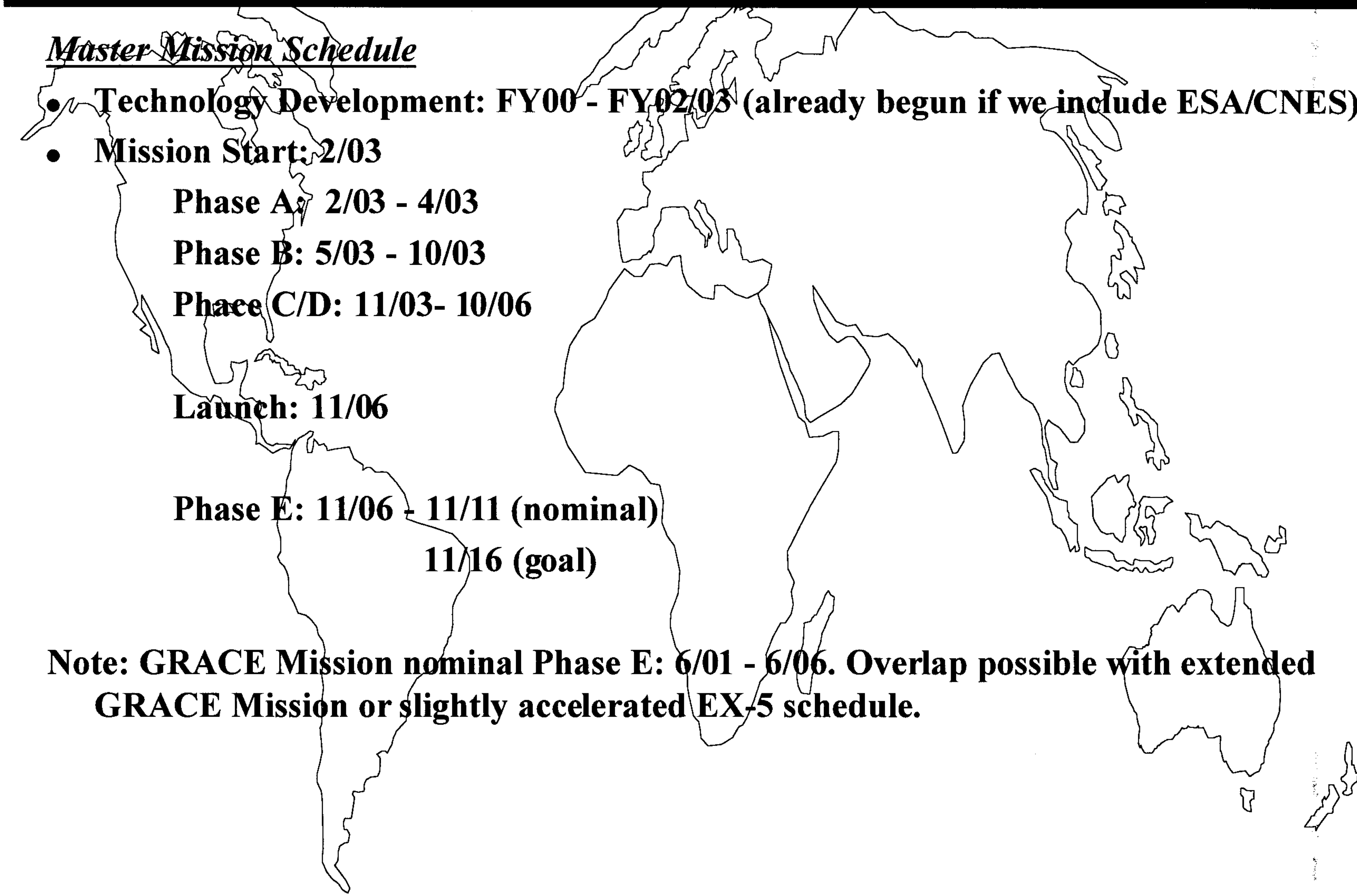

Master Mission Schedule

- **Technology Development: FY00 - FY02/03 (already begun if we include ESA/CNES)**
- **Mission Start: 2/03**

  Phase A: 2/03 - 4/03

  Phase B: 5/03 - 10/03

  Phase C/D: 11/03- 10/06

  Launch: 11/06

  Phase E: 11/06 - 11/11 (nominal)
  11/16 (goal)

Note: GRACE Mission nominal Phase E: 6/01 - 6/06. Overlap possible with extended GRACE Mission or slightly accelerated EX-5 schedule.

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Plan for Remainder of FY00 and FY01:

- **Support New Millenium ST-5 Disturbance Reduction System (selection July 99)**
- **Hold workshop on low-frequency lasers and laser transponders**
- **Develop joint proposal with LISA team for tech dev under NASA's Cross Enterprise Technology Program**
- **Initiate funding for stabilized lasers in space (~$3M)**
- **Begin study of laser transponder system (~$4M)**
- **Work with scientists to understand prospects for accurate removal of atmospheric pressure effects in 2005 - 2010 time frame**

Plan for Remainder of FY99

- **Continue formulation studies to understand performance impacts on science**
- **Continue to understand joint technology (NASA Cross Enterprise Technology Program) development with LISA**

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Improved Science Option

ROM Life-Cycle Costs	***Cost***	***Comments***
I. Technology Investment		
Iodine stabilized laser	**$3M**	**SIM experience**
Inertial sensor	**$1M**	**already funded by CNES**
Micronewton thrusters	**$5M**	**already funded by ESA**
Laser transceiver	**$4M**	**LISA team experience**
II. Formulation Studies	**$10M**	**Team X**
III. Project Management	**$5M**	**over 5yrs, GRACE team, Team X**
IV. Instrument Design/Dev	**$19M**	**LISA team estimate**
V. S/C Design/Dev/I&T	**$105M**	**For 2 sats, Aerospace Sm. Sat. mod**
VI. Ground System Dev	**$5M**	**JPL Adv. Project Design model**
VII. CalVal/Algorithm	**$13M**	**10% of sum of items IV, V, VI**
VIII. Launch Vehicle	**$31M**	**Taurus XL with upper stage motor**
IX. Mission Ops/Data Analysis	**$15M**	**JPL Team X, TMOD experience**
X. Science	**$5M**	**ESSP, JPL Experience**

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Baseline Science Option

ROM Life-Cycle Costs	***Cost***	***Comments***
I. Technology Investment		
Iodine stabilized laser	**$3M**	**SIM experience**
Inertial sensor	**$1M**	**already funded by CNES**
Micronewton thrusters	**$5M**	**already funded by ESA**
Laser transceiver	**$4M**	**LISA team experience**
II. Formulation Studies	**$10M**	**Team X**
III. Project Management	**$5M**	**over 5yrs, GRACE team, Team X**
IV. Instrument Design/Dev	**$17M**	**LISA team estimate**
V. S/C Design/Dev/I&T	**$95M**	**For 2 sats, Aerospace Sm. Sat. mod**
VI. Ground System Dev	**$5M**	**JPL Adv. Project Design model**
VII. CalVal/Algorithm	**$13M**	**10% of sum of items IV, V, VI**
VIII. Launch Vehicle	**$31M**	**Taurus XL with upper stage motor**
IX. Mission Ops/Data Analysis	**$15M**	**JPL Team X, TMOD experience**
X. Science	**$5M**	**ESSP, JPL Experience**

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