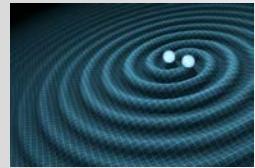


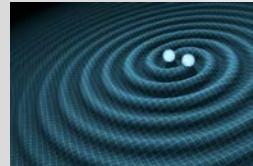
L3 Study Update

David Shoemaker, MIT
L3 Study Group Chair
3 October 2016



L3 Study Team Mission

- LISA is a mission to observe gravitational waves from space
- LISA was prioritized in both the 2000 and 2010 Decadal Reviews
- ESA selected gravitational waves as the science theme for the third large mission (L3) in its Cosmic Vision 2015-2025 Programme
- In Fall 2015, the Astrophysics Subcommittee recommended that NASA, as part of its preparation for the 2020 Decadal Survey, conduct a study in gravitational waves (GW), with the goals of defining the role of NASA in the ESA-led L3 GW mission.
- To this end NASA started the L3 Study to assess options for NASA's participation and to bring the discussion to readiness for the 2020 Decadal Survey
- **The recent 2015 mid-Decadal assessment confirms 2010 recommendations and supports the L3 Study charter**



L3 Study Charter

[http://pcos.gsfc.nasa.gov/studies/L3\)](http://pcos.gsfc.nasa.gov/studies/L3)

- The purpose of the L3 Study is to understand how NASA might participate in ESA's L3 gravitational wave mission, to inform NASA's engagement through the mission's earliest stages, and to prepare for the 2020 decadal survey.

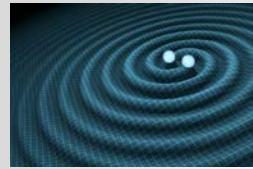
Structure of the study:

- Phase 1 (FY16-17): Analyze the options for NASA participation in the L3 mission and work with the European 'eLISA' consortium on proposals to ESA.
- Phase 2 (FY17-18): Prepare a report to the 2020 decadal survey on NASA's participation in the L3 mission as a minority partner



L3ST Members (announced 01/20/2016)

Members of the L3ST		
Name	Affiliation	Area of Expertise
Baker, John	NASA Goddard Space Flight Center	Theory
Bender, Peter	University of Colorado at Boulder	Instrumentation
Berti, Emanuele	University of Mississippi	Data Analysis/Theory
Conklin, John	University of Florida	Instrumentation
Cornish, Neil	Montana State University	Theory
Cutler, Curt	Jet Propulsion Laboratory	Data Analysis/Theory
Holley-Bockelman, Kelly	Vanderbilt University	Astrophysics
Hughes, Scott	Massachusetts Institute of Technology	Theory/Astrophysics
Larson, Shane	Northwestern University	Analysis/Astrophysics
McWilliams, Sean	West Virginia University	Theory/Data Analysis
Miller, Cole	University of Maryland	Theory
Robertson, Norna	California Institute of Technology	Instrumentation
Shoemaker, David (Chair)	Massachusetts Institute of Technology	Instrumentation
Thorpe, Ira	NASA Goddard Space Flight Center	Instrumentation
Vallisneri, Michele	Jet Propulsion Laboratory	Data analysis
Note: Ex-Officio NASA members of the L3ST: R. Sambruna, A. Hornschemeier, R. Stebbins. In addition, A. Parmar has been appointed by ESA as an observer on the L3ST.		



The Technology Analysis Group (TAG)

- Assist the L3ST with technical analyses

Name	Affiliation
Camp, Jordan	NASA's Goddard Space Flight Center
Klipstein, William	Jet Propulsion Laboratory
Livas, Jeffrey	NASA's Goddard Space Flight Center
McKenzie, Kirk	Jet Propulsion Laboratory
Mueller, Guido	University of Florida
Ziemer, John	Jet Propulsion Laboratory

The union of the L3ST and TAG is the 'L3 Study Group'





ESA Context

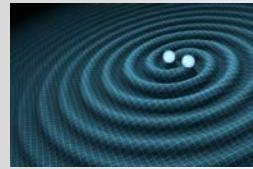
- We have a refined schedule from ESA (Safa, LISA Symp.)
 - Some actions by ESA are being taken more quickly than anticipated in the NASA L3ST charter plan
 - ESA notes that some further compression of the schedule is possible – if technical progress merits it
 - ESA funding for technology development imminent – invitations to tender have been issued

Action	Date	SPC decision to proceed in Phase B1	By mid-2022
Issue Call for L3 mission	Oct 2016		
Mission proposal assessed	Apr 2017	Phase B1 industrial study completed	early 2024
Phase 0 completed	Sept 2017	Mission adoption by the Science Programme Committee	mid-2024
Industrial Phase A completed, including payload definition	S2 2020	Launch	End 2033/early 2034



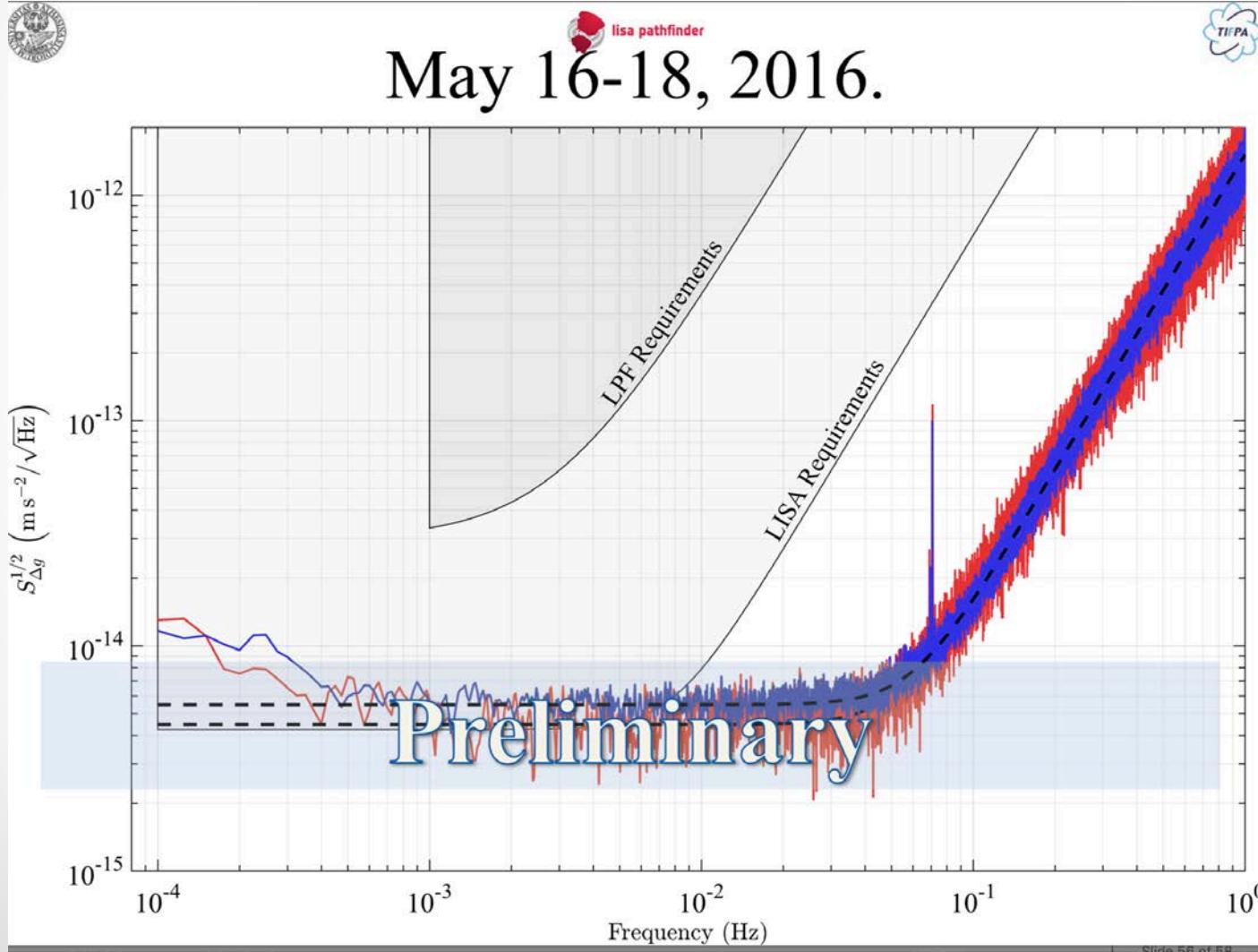
Significant Events since the last update, March 2016

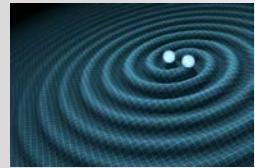
- LISA Pathfinder performing superbly
 - Basic interferometry performing far better than requirements
- LISA Pathfinder has very close coordination US/EU to understand various noise sources in joint US/EU activities – necessary for a mission like LISA to succeed and an important 'demonstration goal'.
 - E.g., at this moment, the European interferometer is sending data to a US computer which will command US microthrusters to steer a European spacecraft around a test-mass of Au-Pt with an RMS error measured in nanometers.



Significant Events since the last update, March 2016

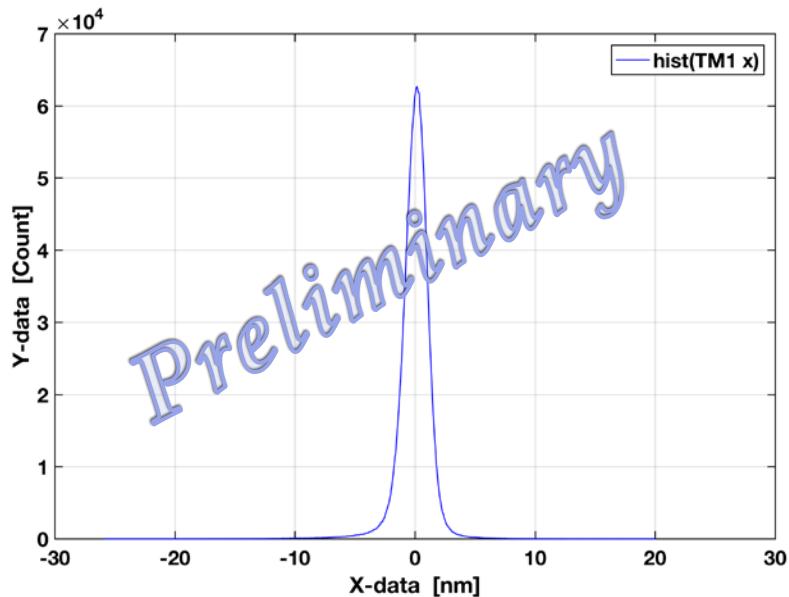
- Drag-free performance exceeds requirements, is at LISA requirement over a broad frequency range



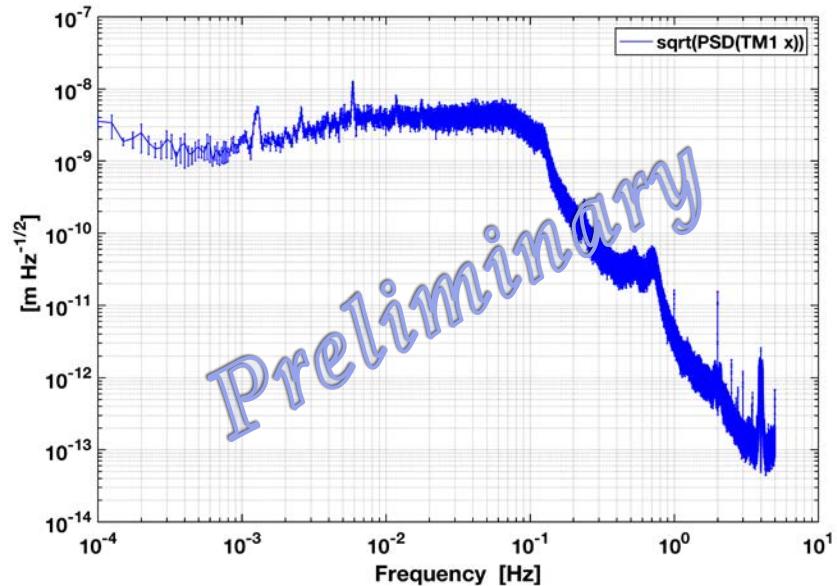


Significant Events since the last update, March 2016

- Pending analysis, looks like US contributions meet requirements
- Control laws and Colloidal Thrusters performing very well



A 3.0.11.dev (R2016a), 2016-09-06 17:25:14.583 UTC, LPF_DA_Module: 9e5f083, ltpda: cfb8077, iplot



3.0.11.dev (R2016a), 2016-09-06 17:27:00.114 UTC, LPF_DA_Module: 9e5f083, ltpda: cfb8077, iplotPSD

Distribution – Standard deviation of 1.6nm, comfortably below +/- 10nm requirement.

Measured displacement error below requirements

Spectrum – Displacement noise at the few nm/rtHz level.



Significant Events since the last update, March 2016

- European 'GOAT' report was issued (<http://www.cosmos.esa.int/web/goat>)
 - Chartered by ESA, to address best technical path for LISA
 - ESA invited strong US participation in GOAT
 - Recommends a full 3-satellite 6-link system (like original LISA) and NASA partnership in ESA mission
- ESA has adopted an accelerated schedule for initial phases of L3/LISA, with a Call in October 2016 and Response by February 2017
 - ESA supportive of US/NASA participation
- LISA Symposium brought EU/US teams and agencies together
 - Presentations by Paul Hertz and Alvaro Giménez (ESA director of Science)
 - Most L3ST members present; many informal discussions, networking
- Mid-Decadal Report is encouraging
 - Recommends a return to the full LISA mission foreseen in 2010



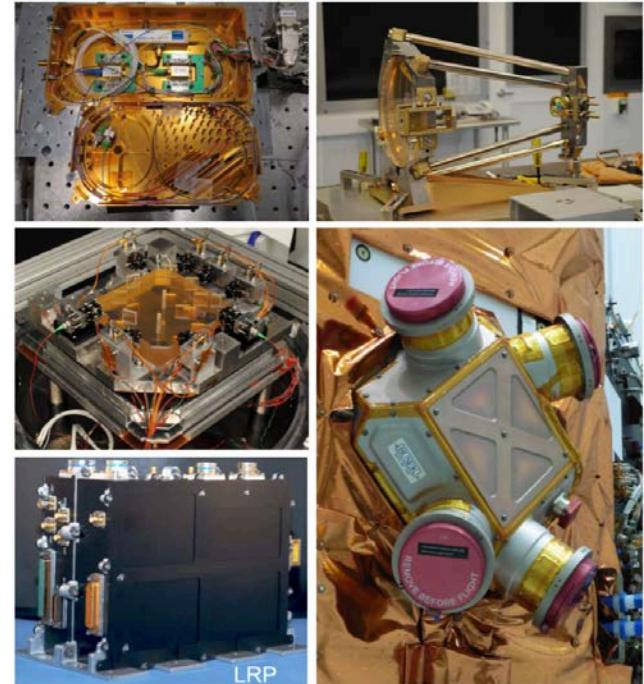
Activities of the L3 Study Group

- Prepared L3ST Interim Report
 - Focuses on Hardware
 - Summarizes the L3ST perspective on priorities
 - Covers the range of technologies and US history and L3ST interests
- The main deliverable is a set of matrices, outlining the options and their cost to NASA
- Also: L3ST observations on value of various potential contributions
- Intended to be of assistance to the APD Director in negotiation with ESA

National Aeronautics and Space Administration



L3 Study Team Interim Report



June 20th, 2016

http://pcos.gsfc.nasa.gov/studies/L3/L3ST_Interim_Report-Final.pdf

www.nasa.gov



Activities of the L3ST

Near-term activities for hardware:

- Support NASA-ESA negotiations on technologies NASA can supply
 - Respond to any needs from NASA negotiators
 - Work with European eLISA Consortium to establish conceptual design, explore targets of opportunity for US contributions
- Develop Technology Roadmap for US effort
 - To pursue a broad range of technologies the US may contribute
 - On a time scale commensurate with the ESA plan
 - Inform NASA Study Office of resources needed



Activities of the L3ST

Near-term activities for Astrophysics/Science:

- What are the prime targets for LISA Astrophysics?
 - Update of 2020 Decadal materials with new understanding and events
 - E.g., the LIGO observations, evolving Astrophysics context
 - The arguments for the 2010 Decadal are still quite compelling
 - Mid-Decadal sees a strengthened science case for mission
- Where are there challenges and opportunities in our understanding of LISA sources?
 - Current understanding supports the science from 2010 decadal
 - Enhanced science opportunities require real research to bring to readiness for the 2020 Decadal



Activities of the L3ST

Near term: Support the European team in responding to the Call for Mission Concepts for the L3 Mission Opportunity

- Responding to invitation from EU 'eLISA' Consortium to engage
- Why is L3ST engaging?
 - Assures a robust response to the Call, putting the overall mission on more sure footing
 - Helps cultivate a unified scientific team with common goals for NASA-ESA partnership
 - Launches the L3ST preparations for the 2020 Decadal – the response to the Call will be a point of departure for more complete documentation
 - Provides a tool to explore the way the US participates in mission
 - 'Member state' role of supplying key measurement technology
 - 'Agency' role of supplying launch/propulsion, system engineering, etc.
- Call expected in October 2016
- Due 3 months later – January/February 2017
- **Expect to have completed L3ST Charter 'Phase 1' deliverables at this time**
-



Plan for 2020 Decadal

L3ST Phase 2 Deliverable

- The L3ST intends to prepare a robust submission to the Decadal
 - This is consistent with our charter
- The full endeavor will be described in terms of the Science and mission to deliver it
 - Enables a proper evaluation by the Decadal Committee
 - Questions of NASA vs. ESA engagement are secondary
- L3ST team will develop the Astrophysics/Science material
 - Drawing in a range of colleagues beyond the L3ST – in US and Europe
- Will require NASA resources appropriate for the Study Team phase for evaluating technical and programmatic aspects, and for supporting the research required to develop a robust Science Case
- Advocacy with the larger scientific community also an important element – presence at meetings covering a range of topics of interest to the Astrophysics/Astronomy community



L3ST

- Next in-person meeting Jan 29-Feb 1 2017 (at APS meeting, Wash DC)
- Context:
 - Response to ESA Call complete
 - Technology Roadmap iterated with Study Office
- Objectives:
 - Robust launch of Decadal-focused activities (Astro focus)
 - Robust launch of Technology Development activities
 - Engagement of the greater US community in the LISA mission