THE LUVOIR MISSION CONCEPT: UPDATE & TECHNOLOGY OVERVIEW

Matthew R. Bolcar
(NASA GSFC)

SPIE Mirror Tech Days
Greenbelt, MD
November 1, 2016

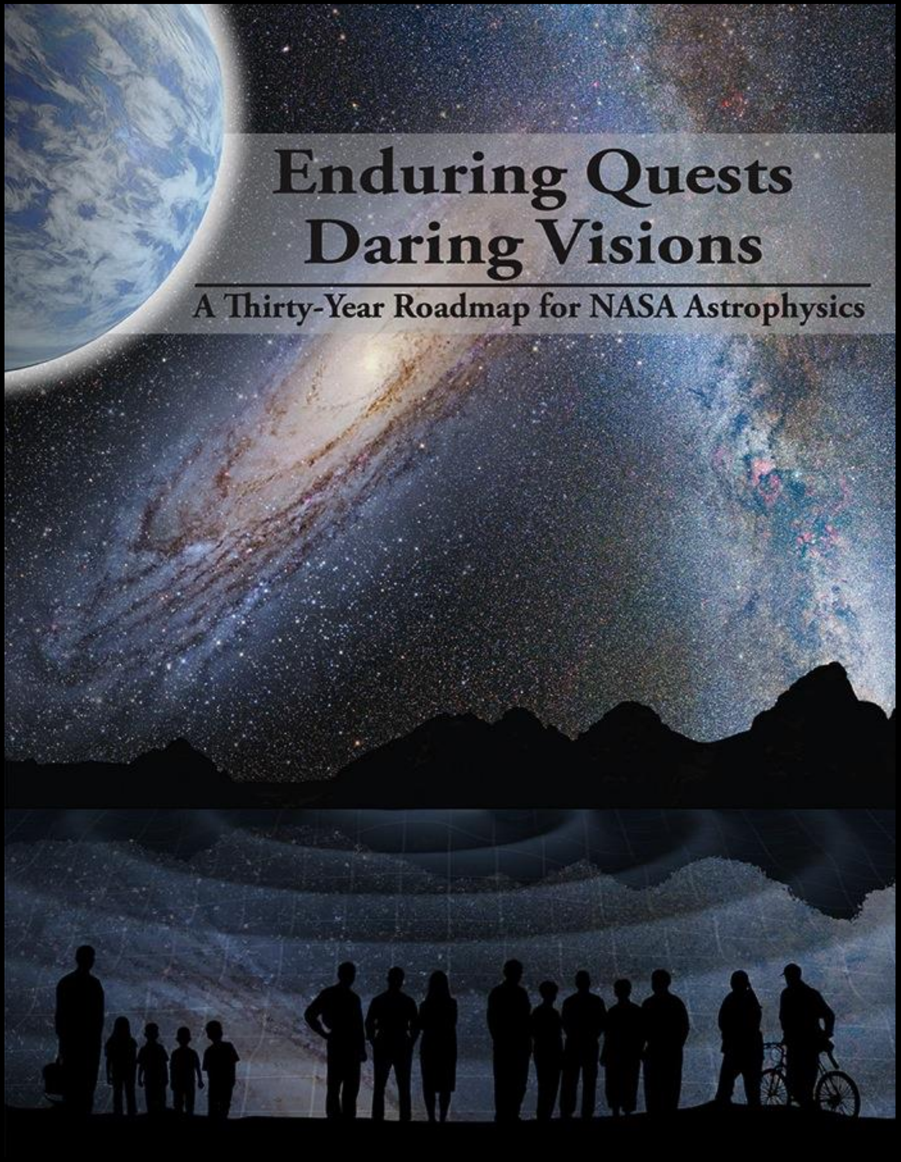
What is the Large UV/Optical/Infrared Surveyor?

General purpose, multi-wavelength observatory with broad science capabilities

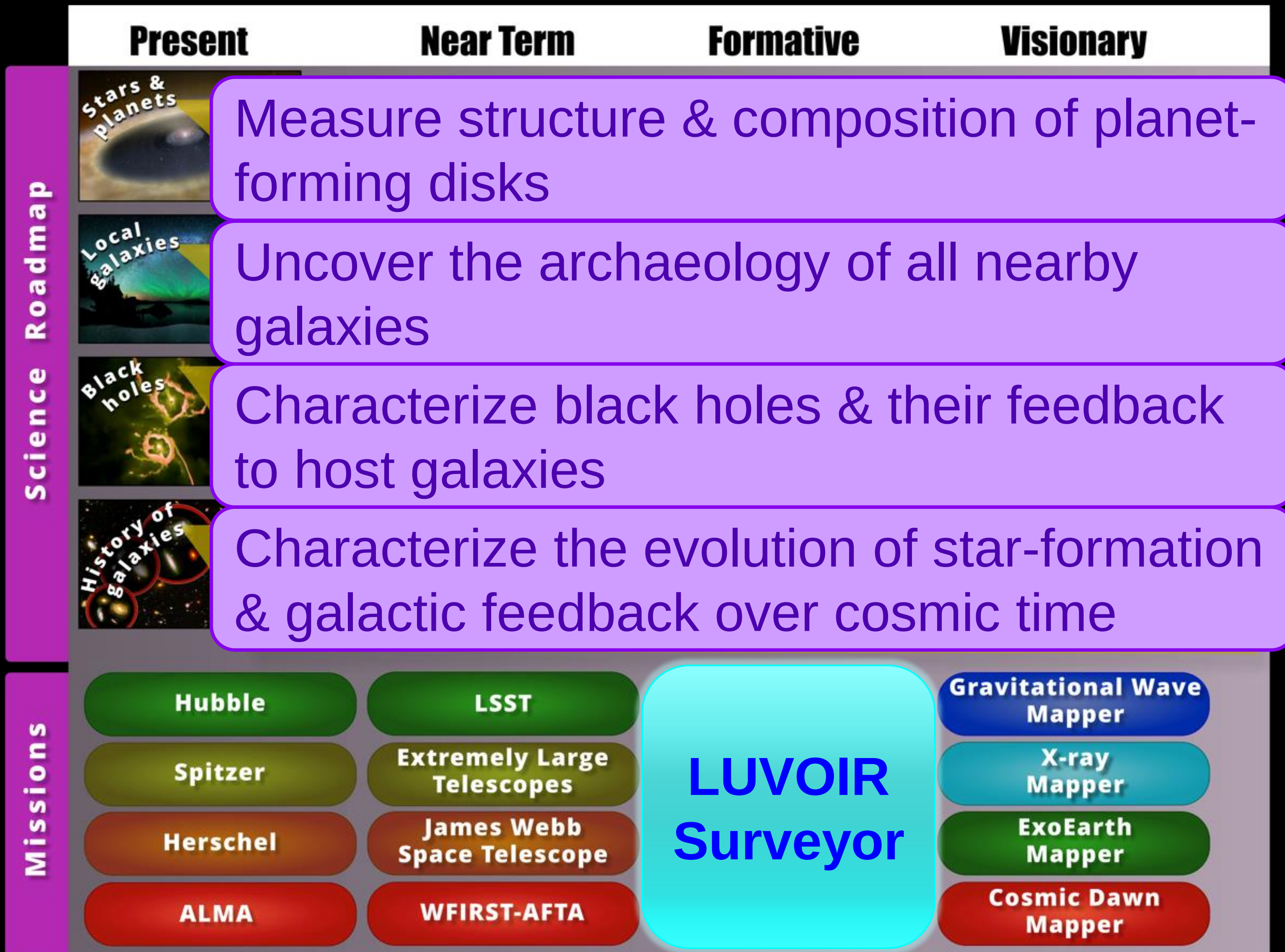
Roots in previous studies over last decade(s):

ATLAST, HDST, etc.

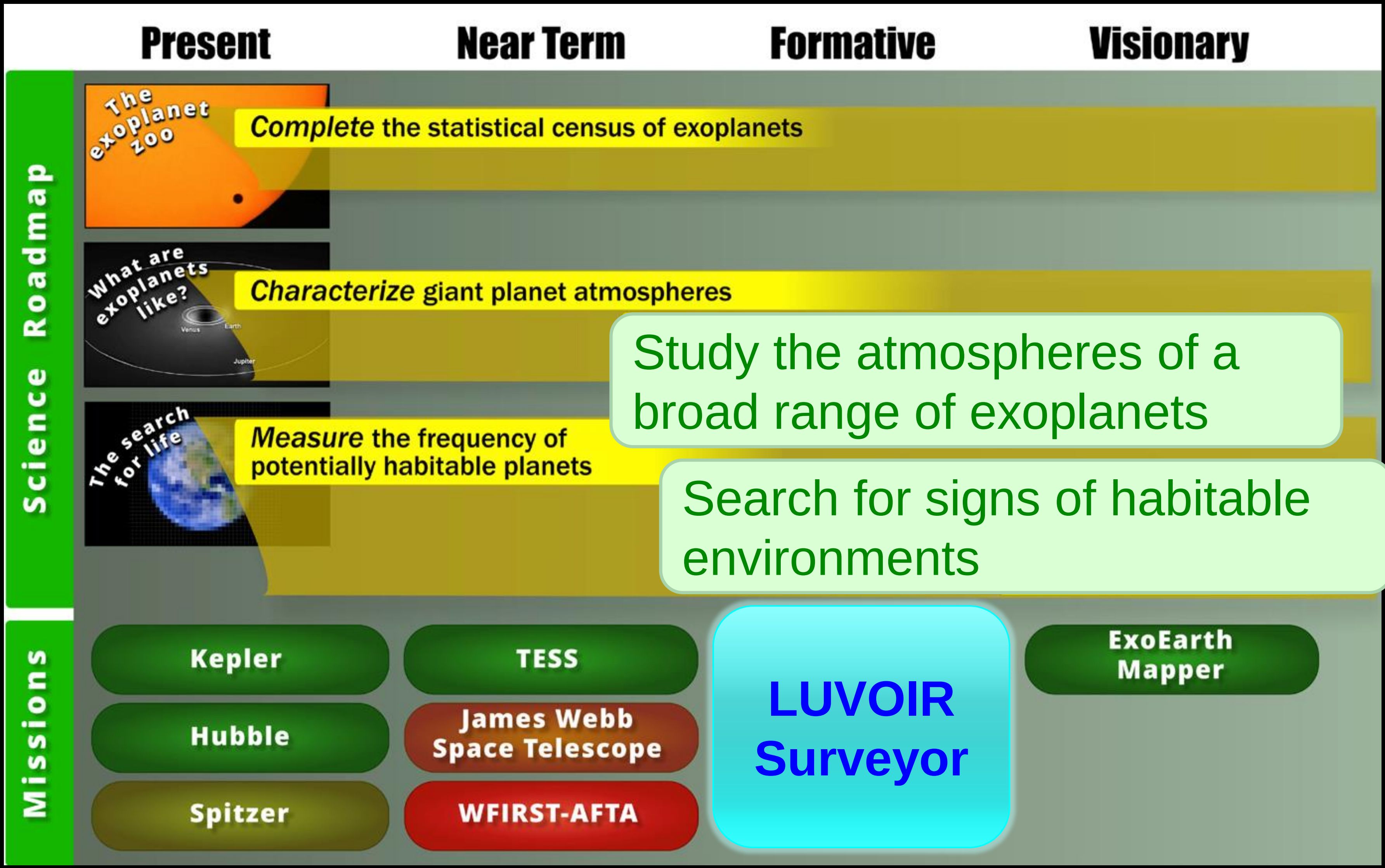
Acronym comes from 2013 Astrophysics Visionary Roadmap



Cosmic origins science goals in Roadmap



Exoplanet science goals in Roadmap



Study Update

Study progress to date:

- 1st Science & Technology Definition Team (STDT) Face-to-Face Meeting (May 2016)
  - Science overview and objectives
  - Initial technology gap assessment
  - Organized into working groups
    - Further develop science objectives, technology needs, and simulation tools

LUVOIR community working groups

Exoplanets

- Leads: Mark Marley (Ames), Avi Mandell (GSFC)

Cosmic Origins

- Leads: John O'Meara (St. Michael's), Jane Rigby (GSFC)

Solar System

- Leads: Walt Harris (LPL), Geronimo Villanueva (GSFC)

Simulations

- Leads: Jason Tumlinson (STScI), Aki Roberge (GSFC)

Technology

- Leads: David Redding (JPL), Matt Bolcar (GSFC)

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  - Science overview and objectives
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  - Organized into working groups
    - Further develop science objectives, technology needs, and simulation tools

- 2nd Face-to-Face Meeting (Aug. 2016)
  - Identified first-generation instrument suite
  - Formed instrument teams to refine science case and performance metrics

Current LUVOIR instrument suite

Optical / NIR Coronagraph – *Laurent Pueyo (STScI)*

- Imaging and low-resolution spectroscopy

UV Multi-Object Spectrograph – *Kevin France (U of Colorado)*

- High-resolution point-source spectroscopy and medium-resolution multi-object spectroscopy

Optical / NIR Wide-field Imager – *Marc Postman (STScI)*

- Imaging (4 – 6 arcmin field-of-view)

Optical / NIR Spectrometer – *Courtney Dressing (Caltech)*

- Multiple resolution modes up to R ~ 10^5
- Point-source / fiber fed

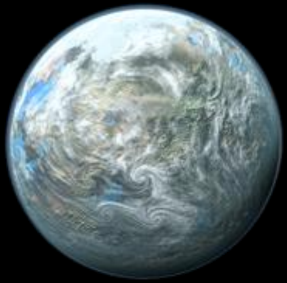
Upcoming work…

- 3rd Face-to-Face Meeting (Nov. 9-10, Yale)
  - Day 1: Select architecture(s) to study
    - Aperture size, on- vs. off-axis, etc.
  - Day 2: Joint meeting with Habitable Exoplanet (HabEx) STDT
    - Collaborate on science & technology topics relevant to both studies

- Dec. 2016 into 2017:
  - Gather inputs from instrument teams
  - Kick-off detailed engineering design studies
    - Integrated Design Center at GSFC

LUVOIR as currently envisaged

Summary of Capabilities



- FUV to NIR wavelength sensitivity
- Suite of imagers and spectrographs
- High-contrast capability (~ 10^{-10})
- Aperture diameter of order 8 – 16 m
- Serviceable (astronaut or robot)
- “Space Observatory for the 21st Century” – decades of science, instrument upgrades (like Hubble), capability to answer questions we have not yet conceived

Technology

The Technology Working Group

- Over 50 members from NASA centers, academia, industry, and international partners

- Six subgroups working on technology areas
  - Coronagraphy
  - Ultra-stable Opto-mechanical Systems
  - Detectors
  - Mirror Coatings
  - Starshades
  - Instrument Components

Initial technology prioritization

- "O1" Deliverable from Study Management Plan
  - Delivered to NASA HQ and Program Offices in June 2016

Prioritization will be revised each June as the Study progresses

Full prioritization report available at: http://asd.gsfc.nasa.gov/luvoir/tech/

Technology Area	Difficulty	Urgency
High-Contrast Segmented-Aperture Coronagraphy	CRITICAL	CRITICAL
Ultra-Stable Opto-mechanical Systems (includes Sensing, Control, Mirrors, and Structures)	CRITICAL	CRITICAL
Large Format, High Sensitivity, High-Dynamic Range UV Detectors	HIGH	HIGH
Vis/NIR Exoplanet Detectors	HIGH	MED
Starshade	HIGH	MED
Mirror Coatings	MED	MED
MIR (3–5 μm) Detectors	LOW	LOW

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Vis/NIR Exoplanet Detectors	HIGH	MED
Starshade	HIGH	MED
Mirror Coatings	MED	MED
MIR (3–5 μm) Detectors	LOW	LOW

Stability for high-contrast is #1 challenge

“*10 pm RMS per 10 minutes*”

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Set by coronagraph's sensitivity to wavefront error.

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"*10 pm RMS per 10 minutes*"

Set by coronagraph's sensitivity to wavefront error.

Set by how fast the wavefront control loop can be closed.

Stability for high-contrast is #1 challenge

"*10 pm RMS per 10 minutes*"

- High-contrast imaging through wavefront ***stability***
  - Stiff, thermally-stable materials and structures
  - Active and passive dynamic isolation
  - Thermal sensing & control at the milli-Kelvin level
  - Metrology to verify performance at the picometer level

Stability for high-contrast is #1 challenge

"*10 pm RMS per 10 minutes*"

- High-contrast imaging through wavefront ***stability***

- High-contrast imaging through wavefront ***control***
  - Slow, low-order wavefront control from stellar photons
  - Fast, higher-order wavefront control from metrology
    - Edge sensors, laser truss, artificial guide star, etc.
  - Go from 10 minutes to seconds or less

Stability for high-contrast is #1 challenge

“*10 pm RMS per 10 minutes*”

- High-contrast imaging through wavefront ***stability***
- High-contrast imaging through wavefront ***control***
- High-contrast imaging through wavefront ***tolerance***
  - Design coronagraphs that can tolerate >10 pm of WFE
  - New optimization techniques open up the design space
    - Vector vortex, aperture masks, nulling interferometry, etc.
  - Tolerate 100s of pm or even nanometers of WFE

Stability for high-contrast is #1 challenge

“*10 pm RMS per 10 minutes*”

- High-contrast imaging through wavefront ***stability***
- High-contrast imaging through wavefront ***control***
- High-contrast imaging through wavefront ***tolerance***
- Solution consists of a combination of all three

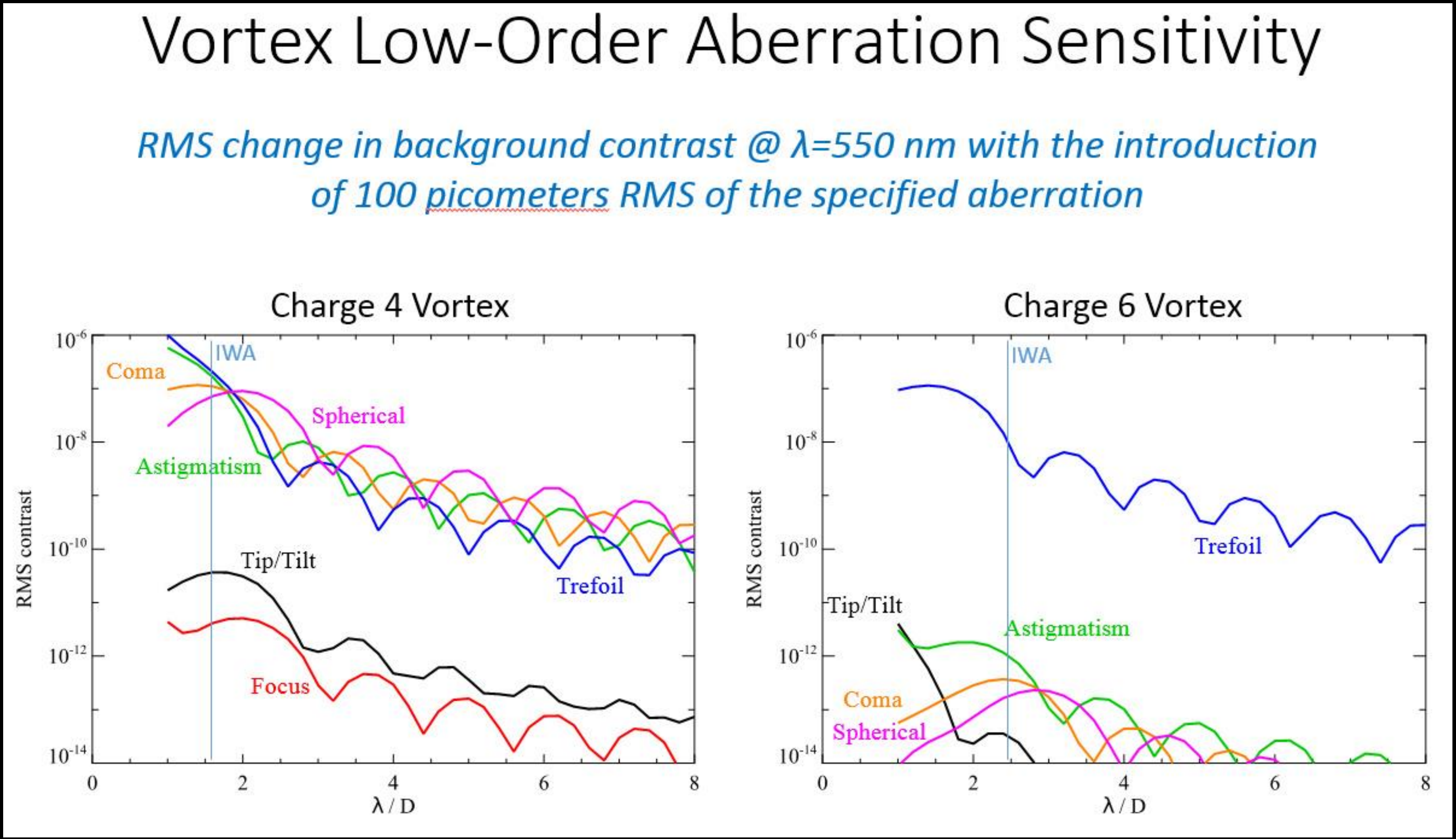
Stability for high-contrast is #1 challenge

"10 pm RMS per 10 minutes"

- High-contrast imaging through wavefront ***stability***
- High-contrast imaging through wavefront ***control***
- High-contrast imaging through wavefront ***tolerance***
- Solution consists o ree

This is the focus of ExEP funding via SAT program and the Segmented Coronagraph Design & Analysis (SCDA) study.

Recent results from vector vortex team:



Courtesy D. Mawet, *et al*.

Stability for high-contrast is #1 challenge

"10 pm RMS per 10 minutes"

- High-contrast imaging through wavefront ***stability***
- High-contrast imaging through wavefront ***control***
- High-contrast imaging ... ***erance***
- Solution consists of a ... e

These two we invite industry / academia to pursue through 2017 SAT, APRA, and SBIR programs.

Stability for high-contrast is #1 challenge

“*10 pm RMS per 10 minutes*”

- High-contrast imaging through wavefront ***stability***
- High-contrast imaging through wavefront ***control***
- High-contrast imaging through wavefront ***tolerance***
- Solution consists of a combination of all three

High-contrast through wavefront ***stability***

- Stable materials
  - Uniform, zero CTE at operation temperature
  - Zero lurch (stable interfaces, no internal stress)
  - High stiffness
  - Zero moisture expansion (CME) after initial release

High-contrast through wavefront ***stability***

- Stable materials

- Dynamic isolation from disturbances
  - Passive reaction wheel isolation
  - Active or passive isolation between SC & telescope
  - Power & data transmission across interface without mechanical short
  - ~140 dB end-to-end isolation

High-contrast through wavefront ***stability***

- Stable materials
- Dynamic isolation from disturbances
- Distributed thermal architecture
  - Cold sunshield with constant temperature
  - Warm-biased telescope
  - Milli-Kelvin sense & control on segments and backplane

High-contrast through wavefront ***stability***

- Stable materials
- Dynamic isolation from disturbances
- Distributed thermal architecture
- Stable-actuators
  - “Set and forget”
  - Low-noise electronics

Stability for high-contrast is #1 challenge

"*10 pm RMS per 10 minutes*"

- High-contrast imaging through wavefront ***stability***
- High-contrast imaging through wavefront ***control***
- High-contrast imaging through wavefront ***tolerance***
- Solution consists of a combination of all three

High-contrast through wavefront ***control***

- Sensing
  - Low/Mid-order wavefront sensing
  - Edge-sensing at primary mirror segments
  - Laser metrology between segments, or PM-to-SM
  - Strain-gauge sensing with actuators
  - Artificial Guide Star (AGS) sensing

High-contrast through wavefront ***control***

- Sensing

- Control
  - Rigid-body segment actuation
  - Deformable mirrors
    - Macro vs. MEMS
    - Continuous vs. segmented
    - High-authority control and location in system
  - PMN vs. piezo actuation

High-contrast through wavefront ***control***

- Sensing
- Control
- Electronics
  - High-digitization (> 20 bit)
  - Multi-plexed
  - Low-noise, stable electronics & cabling

High-contrast through wavefront ***control***

- Sensing
- Control
- Electronics
- Algorithms
  - High-speed
  - Autonomous

State-of-the-Art & TRL

- Many of the previous components are at TRL 3-5
  - Lots of work in mirror development (MMSD, AMTD, AHM, etc.)
  - Disturbance isolation at ~TRL 5-6
  - Deformable mirrors will be TRL 9 with WFIRST
  - Etc.

- Notable exceptions (TRL 1-2?):
  - Artificial guide star
  - Stable structures

- The ***system***, however is TRL 1-2
  - Need ***system-level*** demonstration of stability

For detailed SOA, TRL, gap analysis & references, see: Bolcar, *et al.*, JATIS **2**(4), 2016.

Summary

- LUVOIR Study well underway
  - Diverse participation from academia, industry, NASA centers, and international partners
- Detailed architecture designs of telescope and instruments to begin early 2017
- Technology Working Group hard at work
  - Assessing technologies for current readiness
  - Drafting technology development plan
- Invite industry participation in solving wavefront stability issue with architecture demonstrations

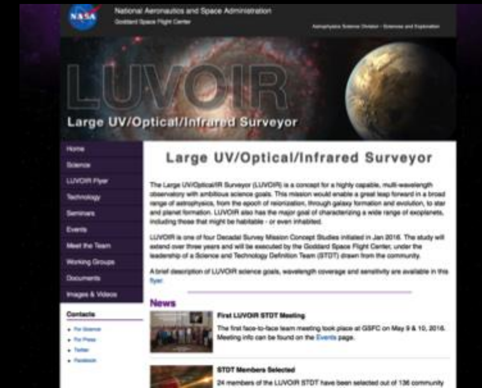
Face-to-face meetings

3rd meeting Nov 9 – 10, 2016 @ Yale University, joint w/ the HabEx team

Observers welcome at all LUVOIR meetings

Backup

Get involved with LUVOIR



Website : http://asd.gsfc.nasa.gov/luvoir/

Contact us!

Study Chairs

- Debra Fischer – debra.fischer@yale.edu
- Bradley Peterson – peterson.12@osu.edu

GSFC Study Scientist & Deputy

- Aki Roberge – aki.roberge@nasa.gov
- Shawn Domagal-Goldman – shawn.goldman@nasa.gov

NASA Program Scientist & Deputy

- Mario Perez – mario.perez@nasa.gov
- Erin Smith – erin.c.smith@nasa.gov

STDT voting members


Debra Fischer
(Yale)


Brad Peterson
(Ohio State / STScI)


Jacob Bean
(Chicago)


Daniela Calzetti
(U Mass)


Rebekah Dawson
(Penn State)


Courtney Dressing
(Caltech)


Lee Feinberg
(NASA GSFC)


Kevin France
(Colorado)


Jay Gallagher
(Wisconsin)


Olivier Guyon
(Arizona)


Walt Harris
(Arizona / LPL)


Mark Marley
(NASA Ames)


Leonidas Moustakas
(JPL)


John O’Meara
(St. Michael’s)


Vikki Meadows
(Washington)


Ilaria Pascucci
(Arizona)


Marc Postman
(STScI)


Laurent Pueyo
(STScI)


David Redding
(JPL)


Jane Rigby
(NASA GSFC)

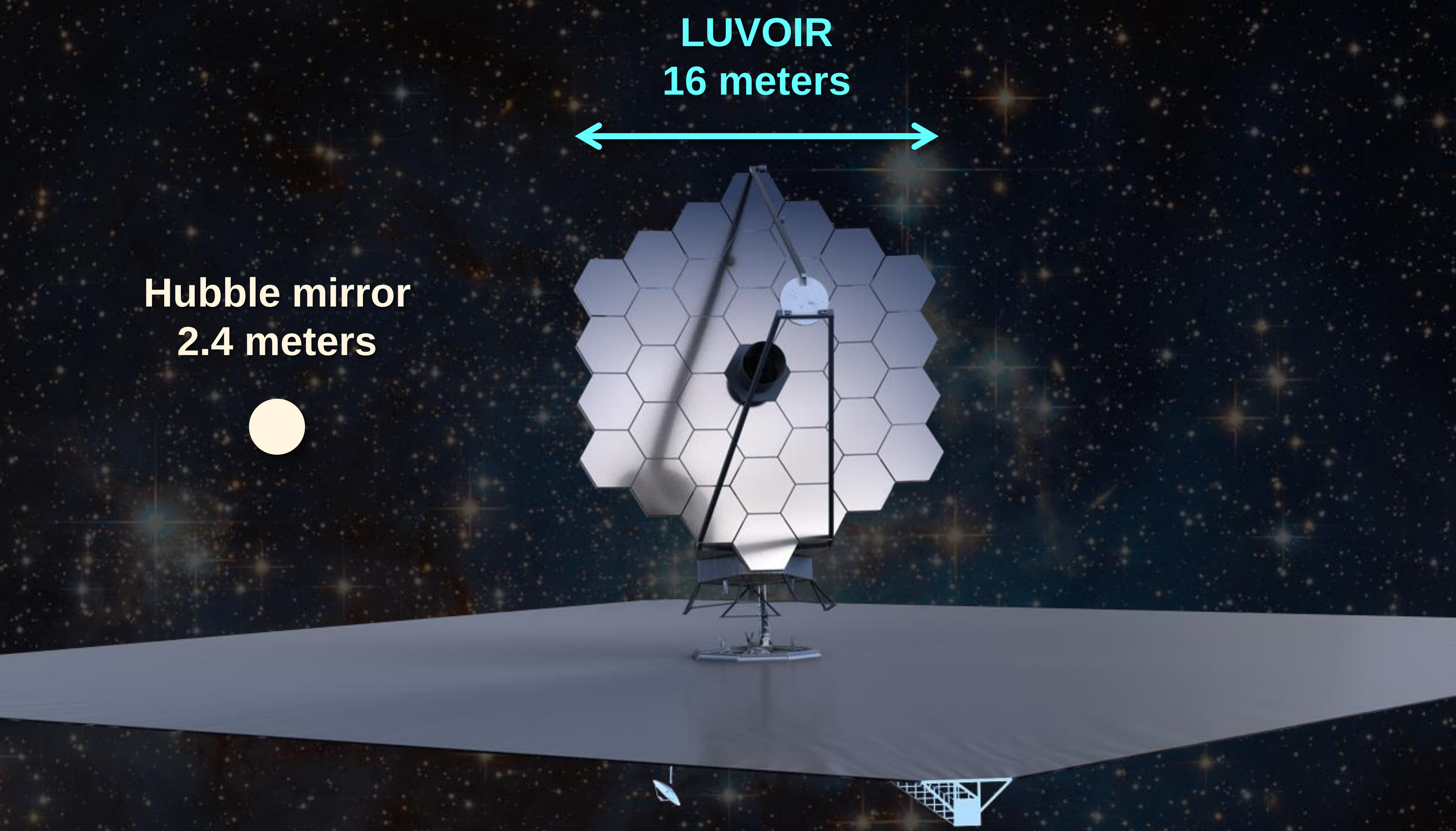

Aki Roberge
(NASA GSFC)


David Schiminovich
(Columbia)


Britney Schmidt
(Georgia Tech)


Karl Stapelfeldt
(JPL)

A possible LUVOIR architecture



"Tech Notes"

- Series of brief, high-level notes
- Intended to inform the STDT on technology challenges and trades:
  - Coronagraphs
  - Starshades
  - Cold Temperature Considerations
  - Long-wavelength Performance
  - Exoplanet Detectors
  - UV Detectors
  - Launch Vehicles
  - Polarization & Coronagraphy
  - UV Coatings & Shortwave Cutoff
- Available at http://asd.gsfc.nasa.gov/luvoir/tech/

Technology Assessments (in progress…)

- ***Rigorous*** assessments of ***demonstrated*** performance for ***specific*** technologies
  - Specific technology components and systems, instead of broad technology areas
  - Demonstrated performance supported by references instead of perceived state-of-the-art
  - Rigorous, quantitative description of test configuration, environment, and results

Technology Assessments (in progress...)

- Distinguish true technology development needs from engineering or manufacturing challenges
- Identify highest-maturity, lowest-risk technologies
- Inform engineering design efforts of likely capabilities
- Draft specific development plans for promising technologies