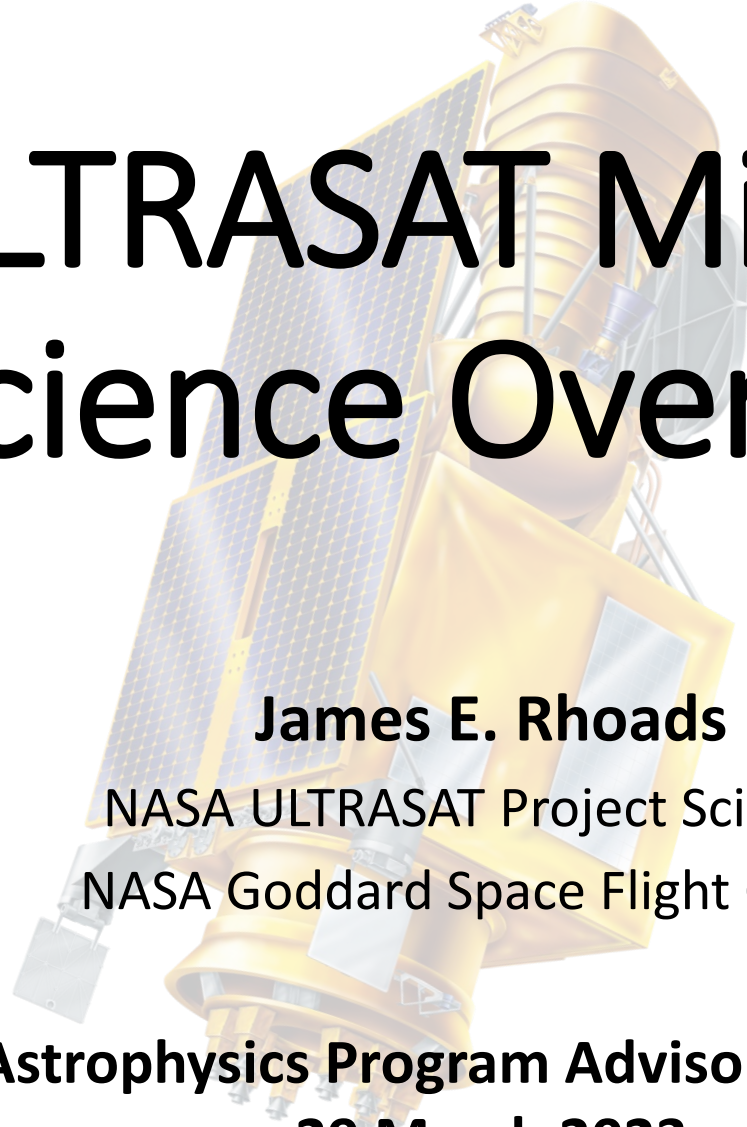
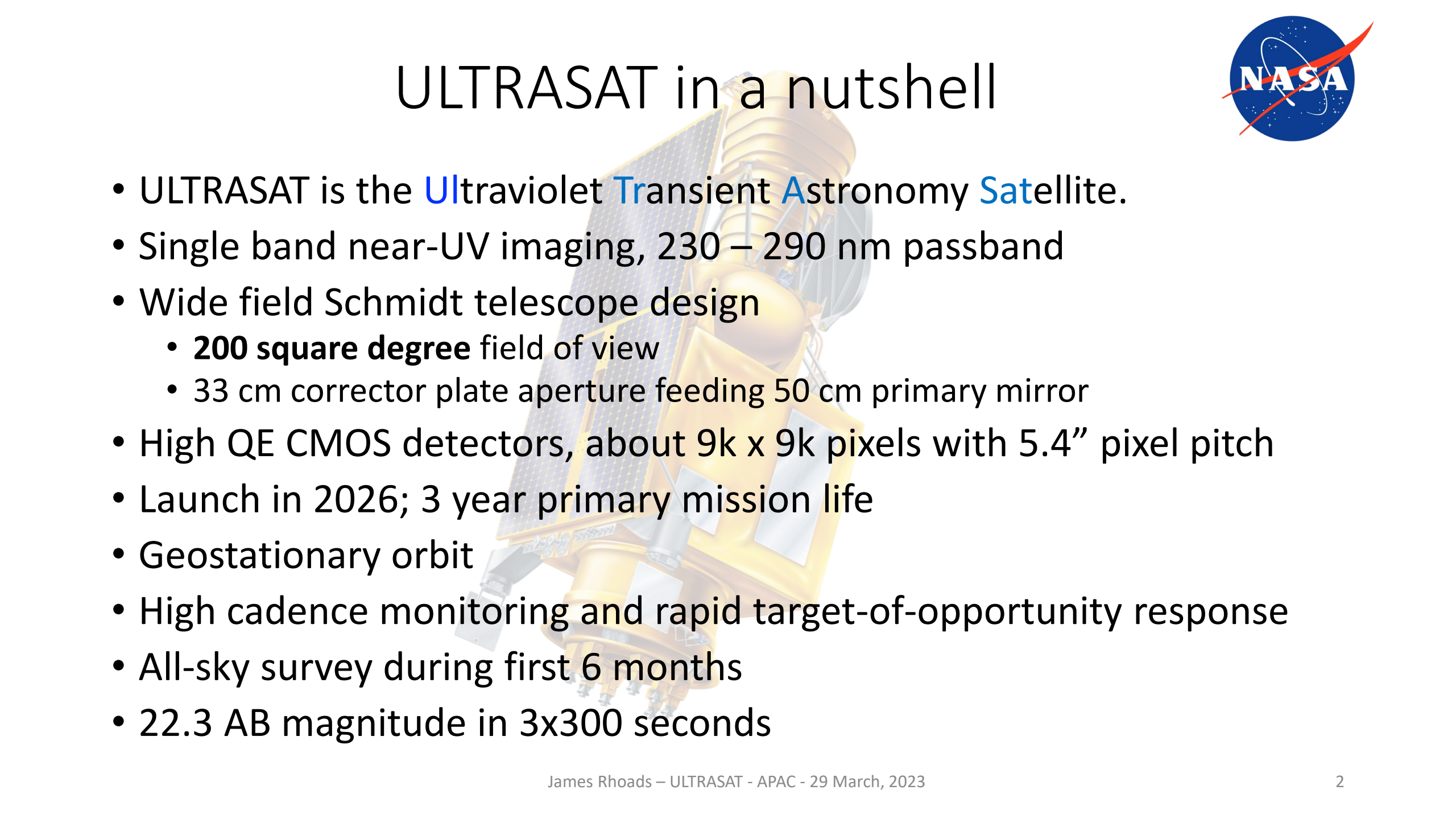


ULTRASAT Mission Science Overview

James E. Rhoads
NASA ULTRASAT Project Scientist
NASA Goddard Space Flight Center

Astrophysics Program Advisory Council
29 March 2023

ULTRASAT in a nutshell



- ULTRASAT is the Ultraviolet Transient Astronomy Satellite.
- Single band near-UV imaging, 230 – 290 nm passband
- Wide field Schmidt telescope design
  - **200 square degree** field of view
  - 33 cm corrector plate aperture feeding 50 cm primary mirror
- High QE CMOS detectors, about 9k x 9k pixels with 5.4” pixel pitch
- Launch in 2026; 3 year primary mission life
- Geostationary orbit
- High cadence monitoring and rapid target-of-opportunity response
- All-sky survey during first 6 months
- 22.3 AB magnitude in 3x300 seconds

ULTRASAT Partnership & NASA Role

ULTRASAT is an Israeli mission with US & German participation.

- Weizmann Institute in Israel is the lead institution. The spacecraft and telescope are being built by Israeli aerospace contractors. The camera is being built by DESY in Germany.
- NASA's roles:
  - Launch ULTRASAT
  - Select and fund participating scientists who will join ULTRASAT working groups, and have data access during the 1-year proprietary period
  - Provide a US based science archive
  - Participate in the definition of transient alerts issued by ULTRASAT
- ULTRASAT is also negotiating a partnership with the Vera Rubin Observatory / LSST.

ULTRASAT and NASA science goals are well aligned

- The 2020 Decadal Survey identified three broad scientific themes:
  - **Worlds and Suns in Context**
  - **New Messengers and New Physics**
  - **Cosmic Ecosystems**
- ULTRASAT will contribute to all three
- ULTRASAT is particularly relevant to the Time Domain And MultiMessenger Astrophysics research called out in the Decadal Survey

- We will strive to observe NASA's core values of Safety, Integrity, Teamwork, Excellence, and Inclusion in our ULTRASAT partnership.

International Agreement

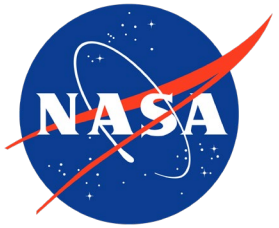
NASA's partnership with the ULTRASAT project is based on an agreement with the Israel Space Agency:

The "Implementing Arrangement between NASA and ISA for Cooperation on the ULTRASAT Mission"

(Hereafter the "IA")

- Signed on 12 February 2023.
- Governed by a pre-existing "Framework Agreement between NASA and ISA for Cooperation in Aeronautics and the Exploration and Use of Airspace and Outer Space for Peaceful Purposes", which was signed in 2015.

NASA ULTRASAT Project Organization



NASA Headquarters

Mark Clampin, Division Director
Sandra Cauffman, Deputy Deputy Division Director

Shahid Habib
Overall Program Management
Valerie Connaughton Program Scientist
Sanaz Vahidinia Deputy Program Scientist

Astrophysics Division

Jennifer Mason
International Coordination
Office of International and
Interagency Relations

IPAC / IRSA
NASA ULTRASAT Archive

George Helou
IPAC Director
Vandana Desai
IRSA Science Lead

NASA
Goddard Space Flight Center
Flight Programs Directorate

Barbara Grofic
Project Management
Cathy Barclay, Deputy

NASA
Kennedy Space Center
Launch Services Program Office

US Participating
Scientist Program

James Rhoads
Project Scientist

Shaun Daly
Mission Manager

Mark Matsumura
Systems Engineering

Aaron Fournier
Integration Engineer

Malcolm Boston
Program Integration Manager

Radford Perry
Contamination
Control

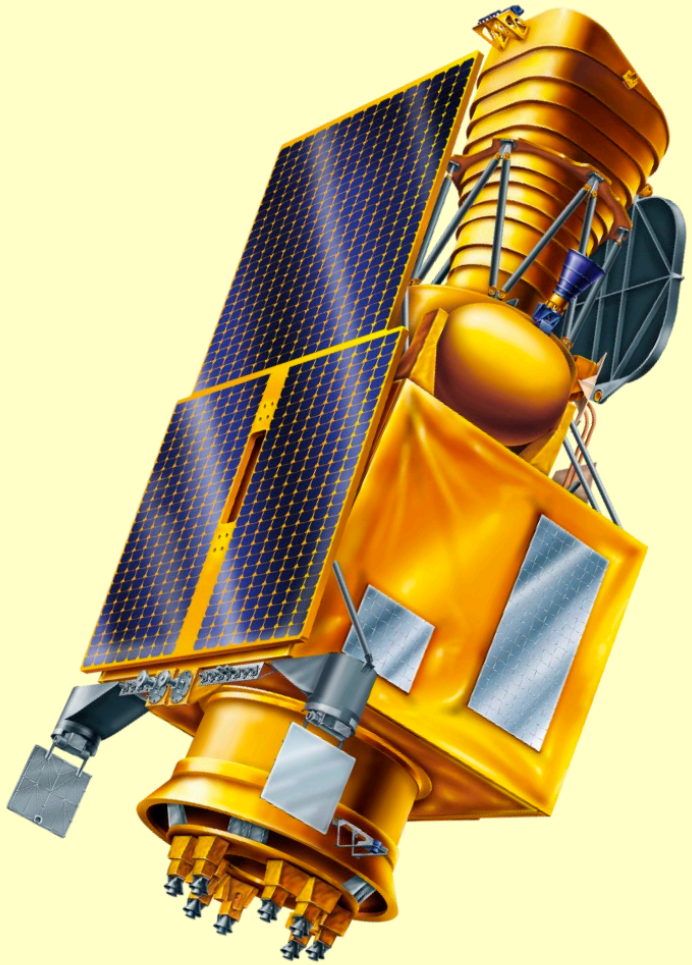
Dan Helfrich
Mechanical
Systems

Paul Mason
Guidance,
Navigation & Control

Updated 26 March 2023

Project Leadership in Israel*

Revolutionize our understanding of the hot transient Universe



PI	E. Waxman (WIS)
Program Manager	U. Netzer (ISA/WIS)
Deputy PI	A. Gal-Yam (WIS)
Camera PI	D. Berge (DESY)
Project Scientist	Y. Shvartzvald (WIS)
Science Lead	E. Ofek (WIS)
Payload Lead	S. Ben-Ami (WIS)
Technology Lead	O. Lapid (WIS)

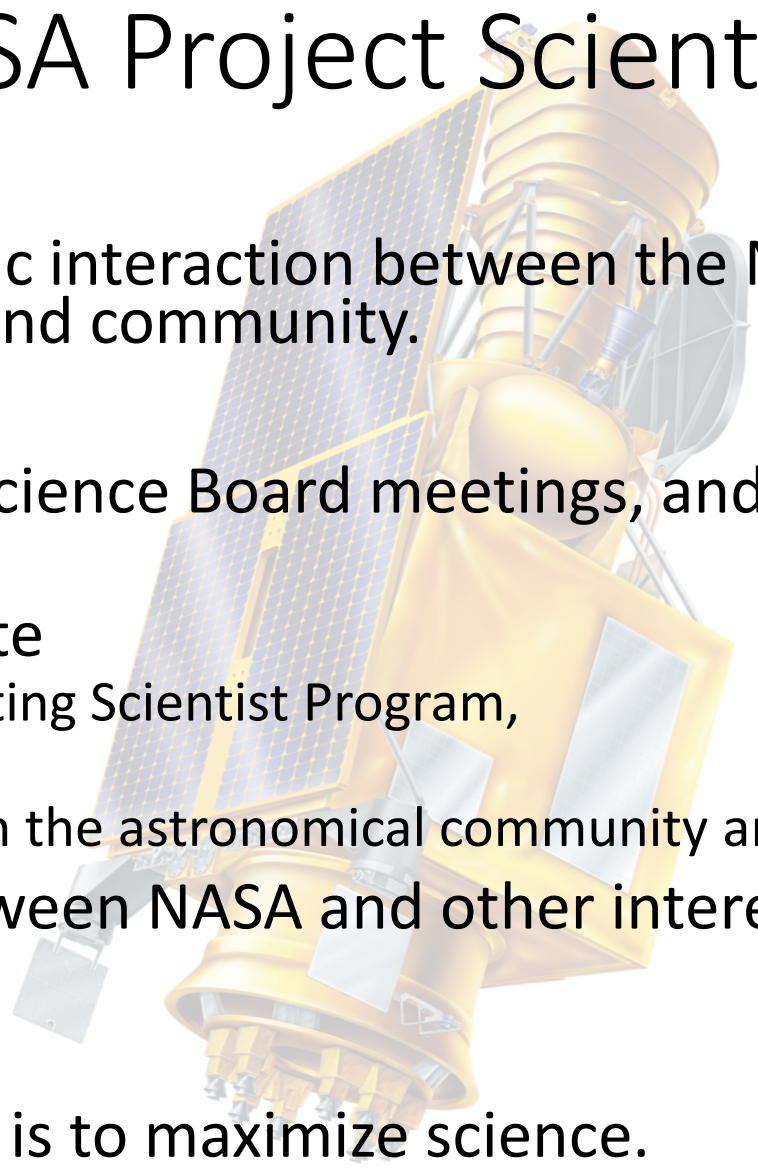
Funding partners
ISA
WIS
DESY
NASA

Industry partners
IAI
Elop
Tower

Chart taken from slide set by Eli Waxman, 1/2023.

* Mostly in Israel;
David Berge is based in Germany

The NASA Project Scientist role

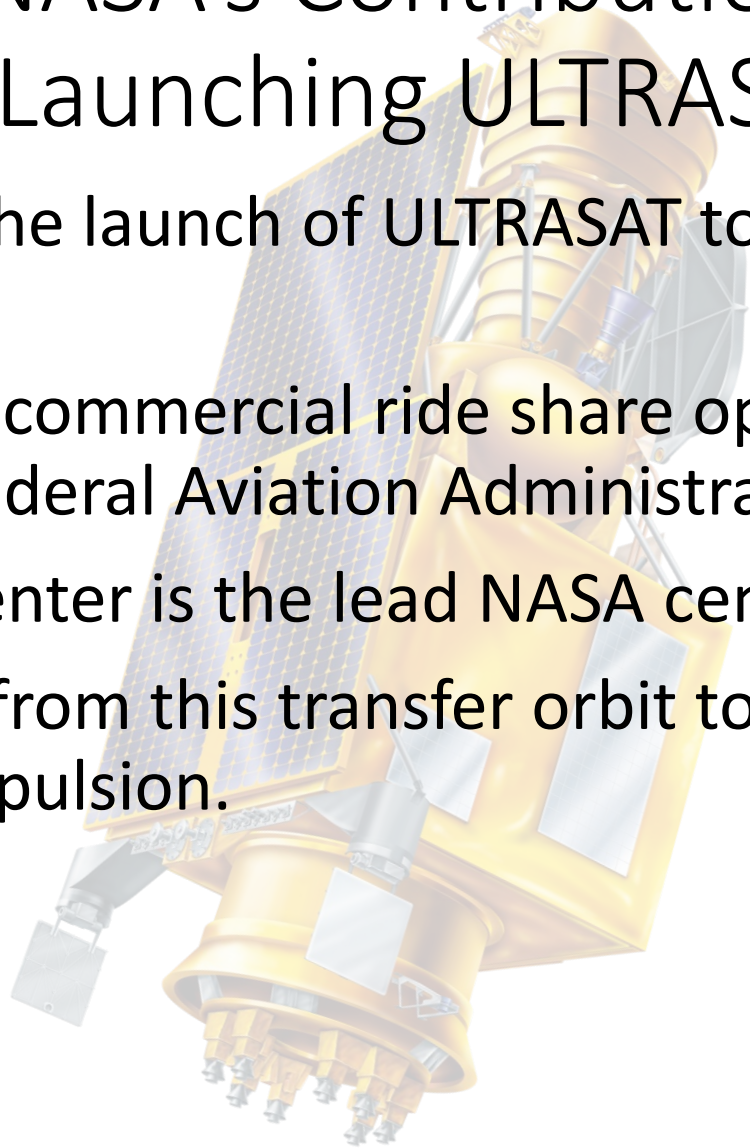


- Coordinate scientific interaction between the NASA community and the ULTRASAT project and community.

- Attend ULTRASAT Science Board meetings, and other ULTRASAT project meetings;
- Support / coordinate
  - NASA's Participating Scientist Program,
  - NASA's archive;
  - Outreach to both the astronomical community and broader public
- Provide liaison between NASA and other interested parties, including Vera Rubin Observatory.

The overarching goal is to maximize science.

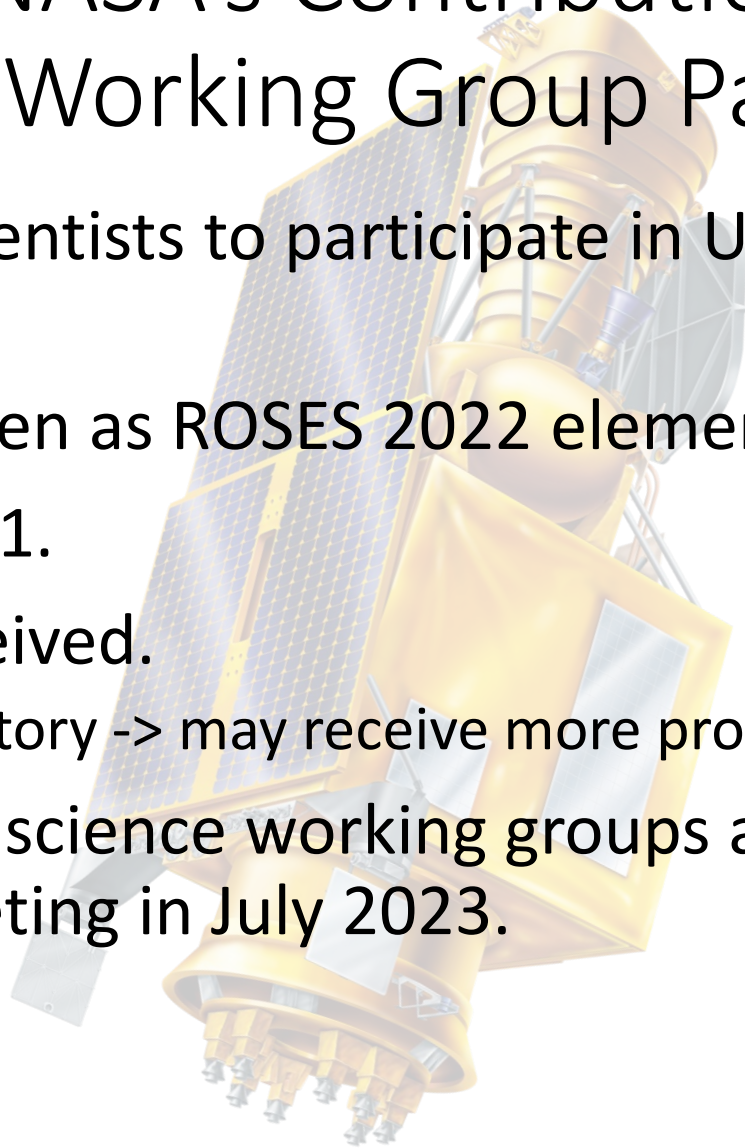
NASA's Contributions: Launching ULTRASAT



NASA will arrange the launch of ULTRASAT to a Geostationary Transfer Orbit (GTO).

- NASA is exploring commercial ride share options for this launch certified by the Federal Aviation Administration (FAA).
- Kennedy Space Center is the lead NASA center for the launch.
- ULTRASAT will go from this transfer orbit to its final operational orbit under its own propulsion.

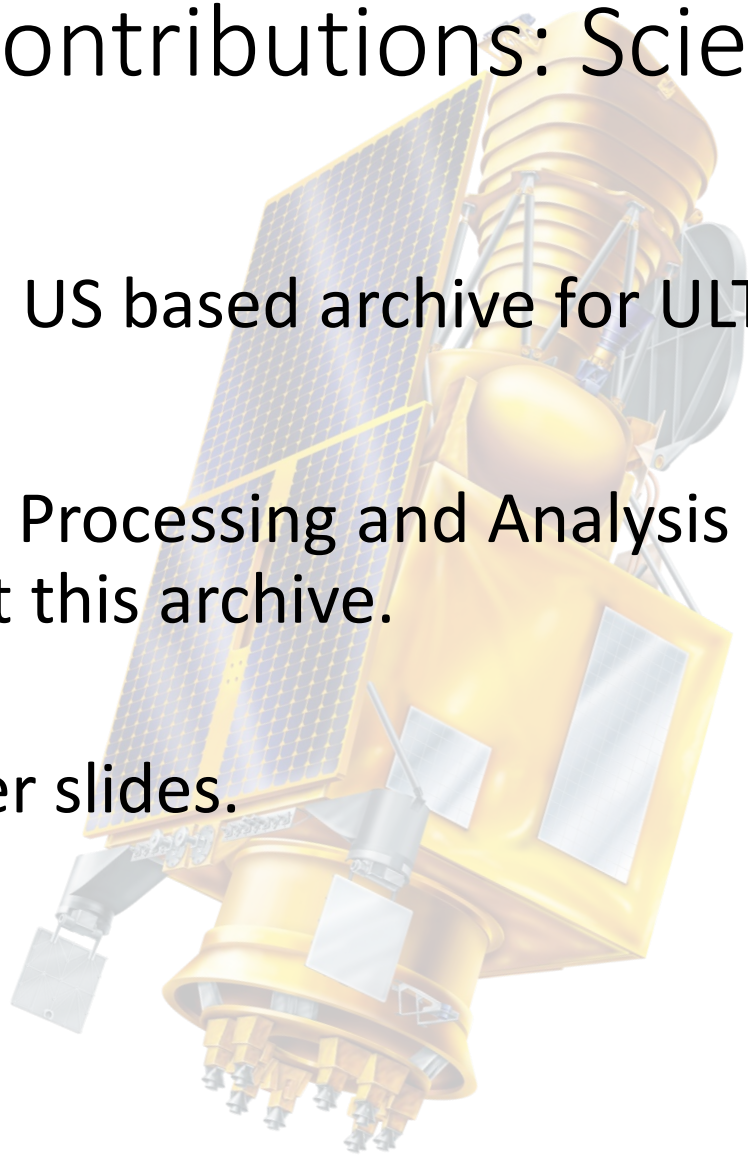
NASA's Contributions: Science Working Group Participation



NASA will select scientists to participate in ULTRASAT working groups.

- Proposal call is open as ROSES 2022 element D.19.
- Due date March 31.
- 32 NOIs were received.
  - (NOIs not mandatory -> may receive more proposals)
- US participants in science working groups are expected to join a collaboration meeting in July 2023.

NASA's Contributions: Science Archive



NASA will support a US based archive for ULTRASAT data.

- IPAC (The Infrared Processing and Analysis Center) in Pasadena, California will host this archive.
- More detail in later slides.

ULTRASAT: Key Science Goals

Slide from Eli Waxman's presentation at AAS Splinter Session, January 2023

<u>EM counterparts to GW sources</u>

Starting 2026: ~ 10 NS-NS merger events per year, ~100 deg^2 error boxes.

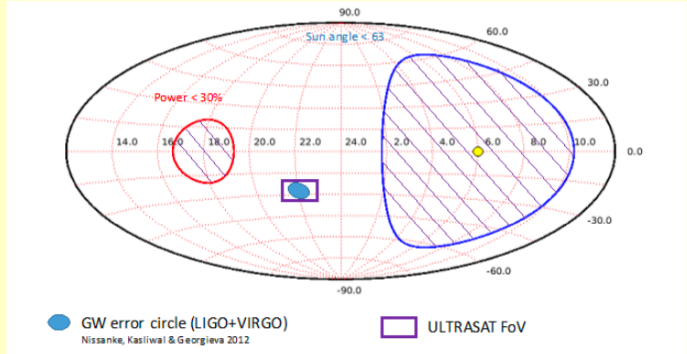
ULTRASAT will provide:

- Fast localization of NS-NS/BH mergers-
  Rapid, <15min, access to >50% of sky,
  Cover GW error box in a single image.
- UV light curves to measure ejecta properties.

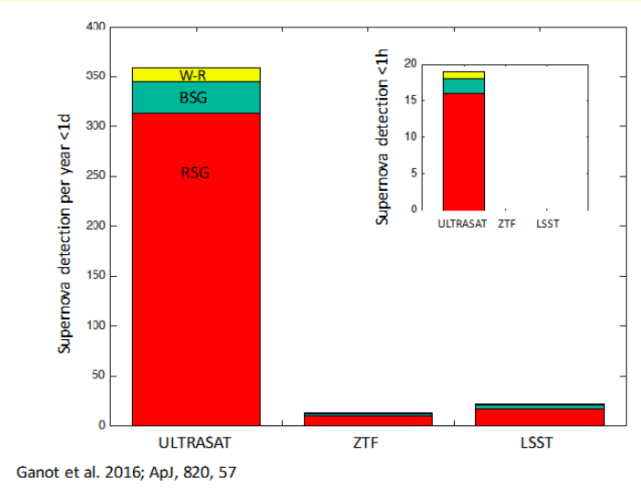
<u>Deaths of massive stars</u>

- High quality early high cadence UV data,
  Rapid alerts for follow-ups,
  100's of SNe including rare types.
- Measure properties of supernova progenitors.
- Map progenitors to supernova types.
- Reveal pre-explosion evolution and mass loss.

ULTRSAT's ToO access



Rates of early detections of SNe



Ganot et al. 2016; ApJ, 820, 57

ULTRASAT Science Working Groups

ULTRASAT science efforts are coordinated through a set of topical working groups (WGs).

WGs are advisory to the ULTRASAT Science Board, which in turn is advisory to the ULTRASAT Principal Investigator.

Each WG is expected to define key science questions to be addressed, the measurements needed, etc, for its science area.

WG1 & WG2 address ULTRASAT “Key Goals.”
U.S. participation in the Transient Alerts WG (WG12) is explicitly called out in the Implementing Arrangement.

- WG1 - Transient Stellar Explosions
- WG2 - Gravitational Wave Sources
- WG3 - Exoplanets and Star-Planet Connection
- WG4 - Cosmology
- WG5 - Stars, Stellar Structure and Evolution
- WG6 - Galaxies
- WG7 - AGN
- WG8 - TDEs
- WG9 - Solar system
- WG10 - GRBs
- WG11 - Data Analysis
- WG12 - Transient Alerts
- WG13- Follow Up

NASA Interests and ULTRASAT Working Groups

NASA's top level astrophysics goal leads to three broad questions, and NASA has three corresponding Program Offices. All three overlap with multiple ULTRASAT science working groups, *approximately* as follows:

How did we get here? – Explore the origin and evolution of galaxies, stars, and planets.	**How does the universe work? – Probe the origin and destiny of our universe, including the nature of black holes, dark energy, dark matter, and gravity**	**Are we alone? – Discover and study planets around other stars, and explore whether they could harbor life.**
Cosmic Origins (COR) program office	Physics of the COSMOS (PhysCOS) program office	Exoplanet Exploration (EXEP) program office
WG4 Cosmology	WG1 Transient Stellar Explosions	WG3 Exoplanets & Star-Planet Connection
WG6 Galaxies	WG2 Gravitational Wave Sources	WG5 Stars, Stellar Structure, and Evolution
WG7 Active Galactic Nuclei	WG8 Tidal Disruption Events	WG9 Solar System
	WG10 Gamma Ray Bursts	
---------- WG11 Data Analysis; WG12 Transient Alerts; WG13 Follow-up ----------		

ULTRASAT Alerts

Plans for ULTRASAT's transient alerts:

- Distribution within 20 minutes of detection by ULTRASAT
  - Format of alerts to be "suitable for the US astronomical Community," with details to be mutually defined in the Transient Alerts Working Group.
  - Includes time, location, and source classification information
    - (e.g. transient, stellar variable, solar system object, Active Galactic Nucleus)
  - Includes light curve with, at minimum, time and flux information for the last non-detection, the first detection, and a confirmation.
  - Alerts will be updated as new information is learned that may be of scientific value to follow-up observers, based on criteria to be mutually defined in the Transient Alerts Working Group.

ULTRASAT, NASA, and Rubin Observatory

- The ULTRASAT project is also pursuing collaboration with the Vera Rubin Observatory

- NASA and Rubin Observatory will coordinate efforts with the goal of supporting a cohesive, inclusive US ULTRASAT community.

- Most notably, the open ROSES call for Participating Scientists was drafted with cognizance of Rubin Observatory leadership. The number of US slots in the Working Groups is larger because it includes *both* the NASA and VRO partnerships with ULTRASAT.

US ULTRASAT Archive overview

- The US ULTRASAT archive will be hosted at NASA/IPAC's Infrared Science Archive (IRSA)
- IRSA and the ULTRASAT project will negotiate a Data Transfer Interface Control Agreement (ICA). This will include specifications on metadata, data formats, data transfer mechanics, etc.
- IRSA will develop a User Interface (UI)
  - To include both Graphical User Interface (GUI) & Application Program Interface (API)
  - Based in part on use cases for ULTRASAT data.
- The ULTRASAT Participating Scientists will be a resource IRSA may draw on for help specifying these use cases.
- Documentation:
  - IRSA will share provided documentation about ULTRASAT Data
  - IRSA will provide documentation about data access & IRSA Tools
  - IRSA will provide a help desk function, consulting ULTRASAT project as appropriate for technical questions.

Two ULTRASAT Archives

- **Weizmann Institute of Science (WIS) in Israel**
  - ULTRASAT members will access proprietary data (1 year) from the WIS archive
  - WIS will issue alerts to the entire astronomical community

- **NASA/IPAC Infrared Science Archive (IRSA) in United States**
  - IRSA will provide a permanent science archive containing public ULTRASAT data, documentation, and services to meet the needs of the U.S. research community
  - The ULTRASAT archive at IRSA will follow the standards of NASA Astrophysics Mission Archives
  - Basic data products will be identical with those available at WIS
  - Data access & exploration tools at IRSA will be complementary with those at WIS

Based on Vandana Desai's archive slides from the "Introducing ULTRASAT" AAS splinter session, 11 Jan 2023

ULTRASAT Archive @ IRSA
Public Data Releases

- The ULTRASAT project will deliver images at various processing levels (e.g. raw, processed, mask, difference), as well as catalogs of time domain measurements.

- The first public data release will consist of data from the first 6 months of the mission, representing approximately 230 TB of imaging data and 50 billion rows of catalog data.

- Subsequent data releases will occur annually, with each release covering 12 additional months of data (hence twice the data volume of the first release).

Based on Vandana Desai's archive slides from the "Introducing ULTRASAT" AAS splinter session, 11 Jan 2023

ULTRASAT Archive @ IRSA: Tools

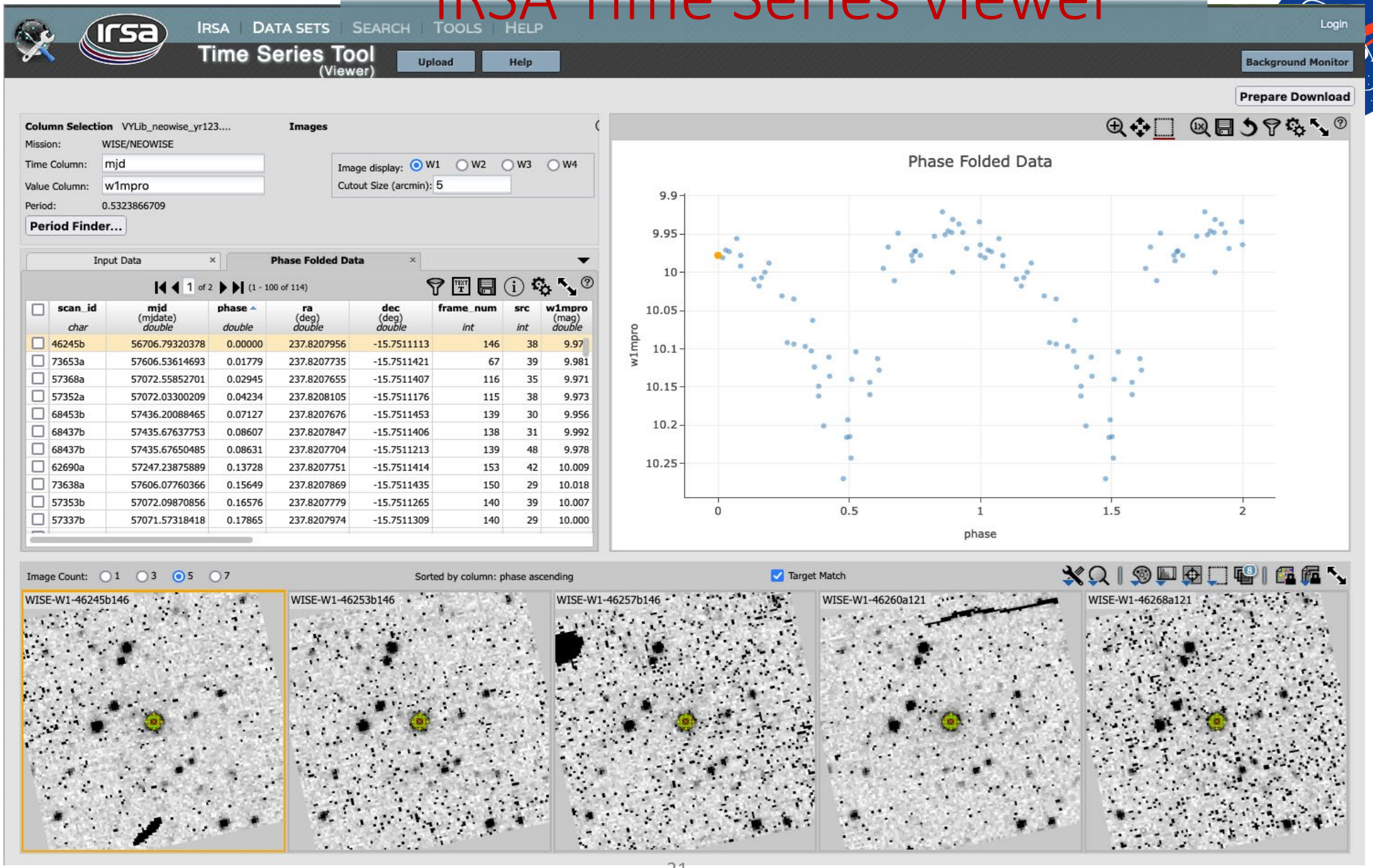
- Data Discovery and Data Access services will be based on Virtual Observatory standards, such as Simple Image Access and Table Access Protocol, standard for NASA Astrophysics Archives

- Data Exploration Tools will focus on variability due to proprietary period
  - Built using open-source “Firefly by IPAC” Archive GUI toolkit developed for Spitzer and extended to meet time domain science needs of WISE/NEOWISE, PTF/ZTF, Rubin Observatory

- Existing IRSA tools that focus on variability
  - Time series viewer & periodogram service
  - Forced photometry service, e.g. ZTF
  - Image Coadder, e.g. WISE

Based on Vandana Desai’s archive slides from the “Introducing ULTRASAT” AAS splinter session, 11 Jan 2023

IRSA Time Series Viewer



Copied from Vandana Desai's archive slides from the "Introducing ULTRASAT" AAS splinter session, 11 Jan 2023

For Further Information

- The ULTRASAT Project web pages in Israel are at https://www.weizmann.ac.il/ultrasat/
  - The working groups are described at https://www.weizmann.ac.il/ultrasat/for-scientists/working-groups/working-groups
  - Presentations from past ULTRASAT scientific workshops are linked from https://www.weizmann.ac.il/ultrasat/events/past-events (including the 1st and 2nd ULTRASAT Science Workshops [6/2020 & 10/2021], and the "Introducing ULTRASAT" AAS Splinter Session [1/2023]).
- The NASA ULTRASAT page is at https://apd440.gsfc.nasa.gov/ultrasat/

- My contact information: James.E.Rhoads@nasa.gov

Questions?