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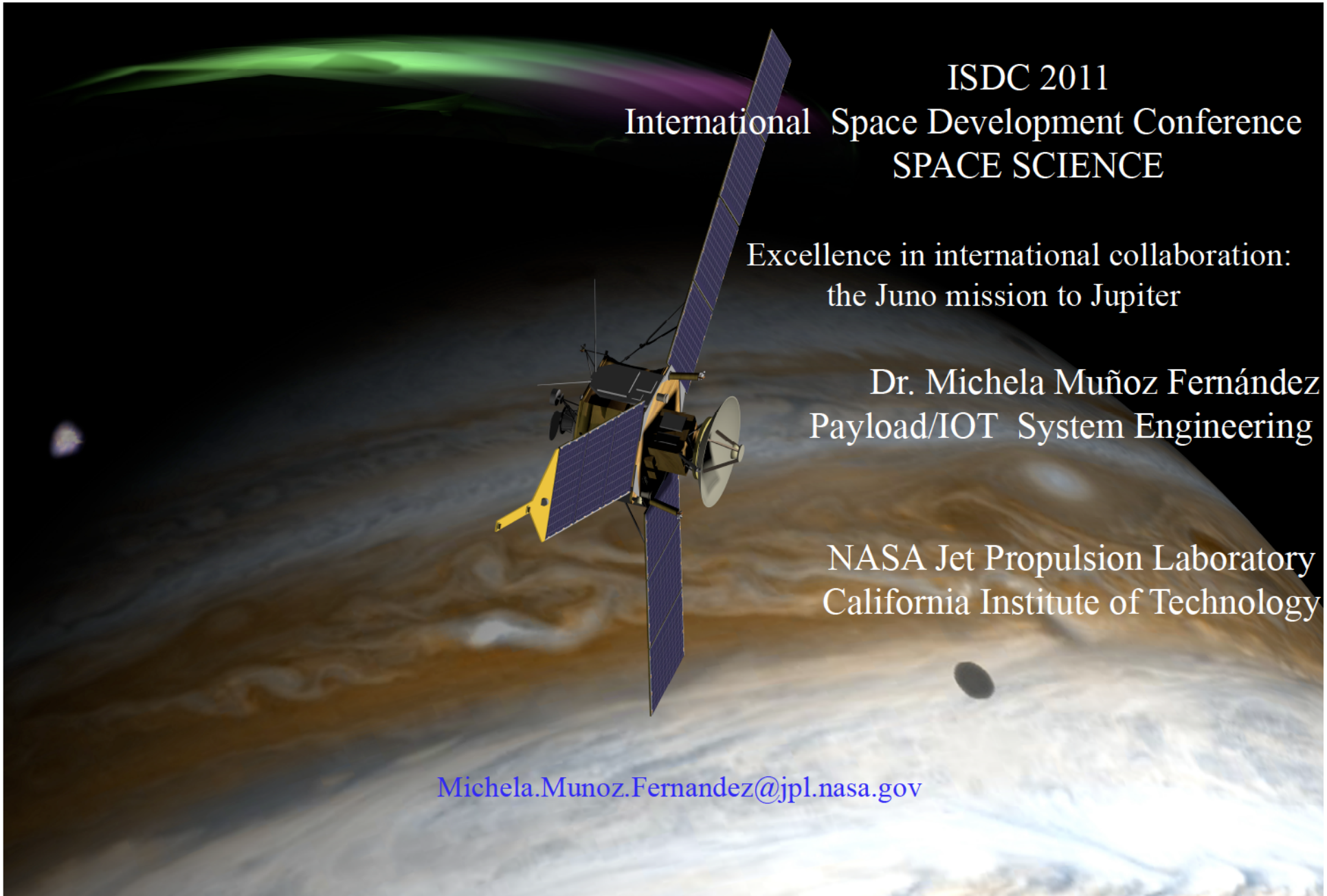

ISDC 2011
International Space Development Conference
SPACE SCIENCE

Excellence in international collaboration: the Juno mission to Jupiter

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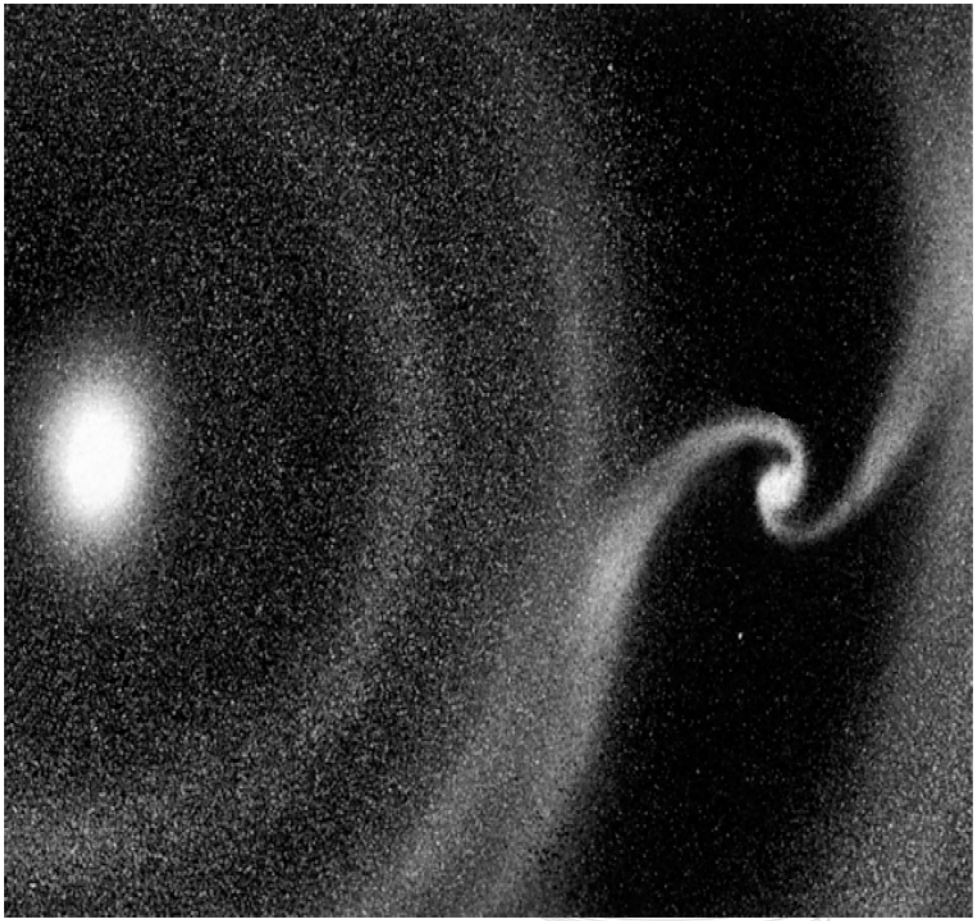
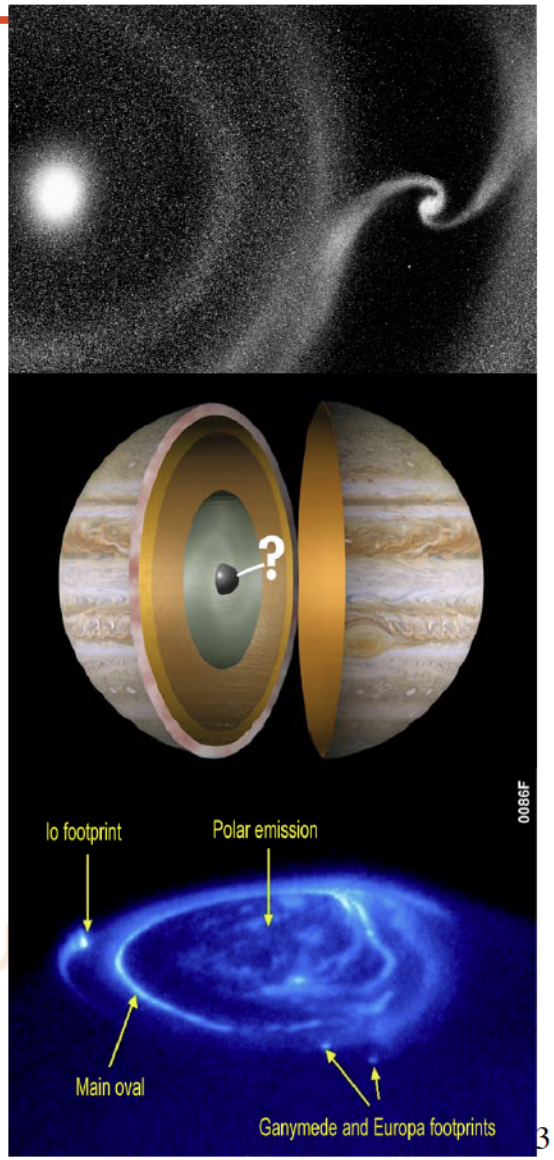
The History of the Solar System

- Present theories of solar system origin and evolution are at an impasse
- Jupiter is the key to the puzzle
- We need to understand how Jupiter was enriched in heavy elements
- These heavy elements are the seeds for the Earth and life



Juno Science Objectives

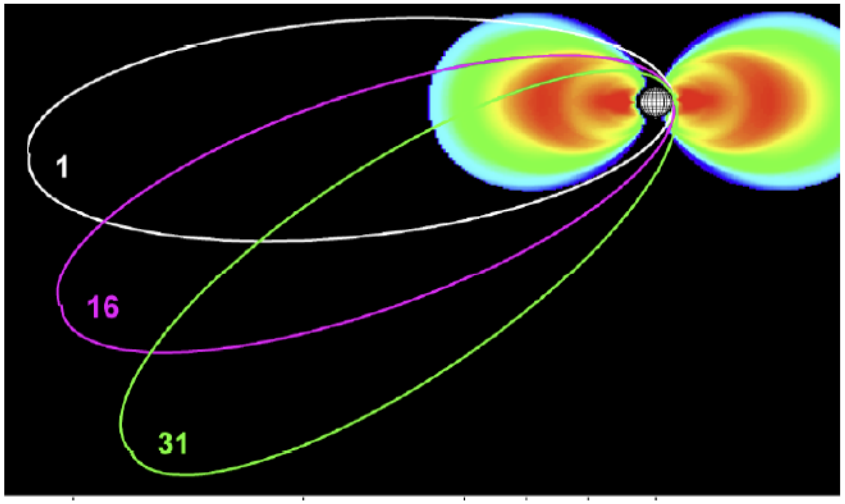
- Origin
  - Determine O/H ratio (water abundance) and constrain core mass to decide among alternative theories of origin.
- Interior
  - Understand Jupiter's interior structure and dynamical properties by mapping its gravitational and magnetic fields.
- Atmosphere
  - Map variations in atmospheric composition, temperature, cloud opacity and dynamics to depths greater than 100 bars.
- Polar Magnetosphere
  - Explore the three-dimensional structure of Jupiter's polar magnetosphere and aurorae.

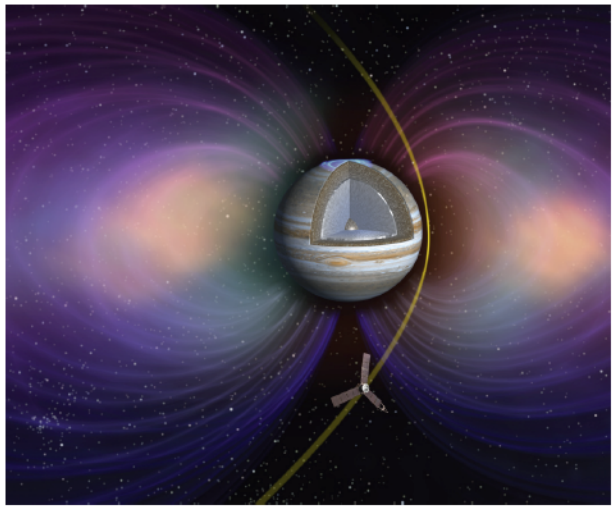


The orbit is the key...

Suite of instruments will collect data on:

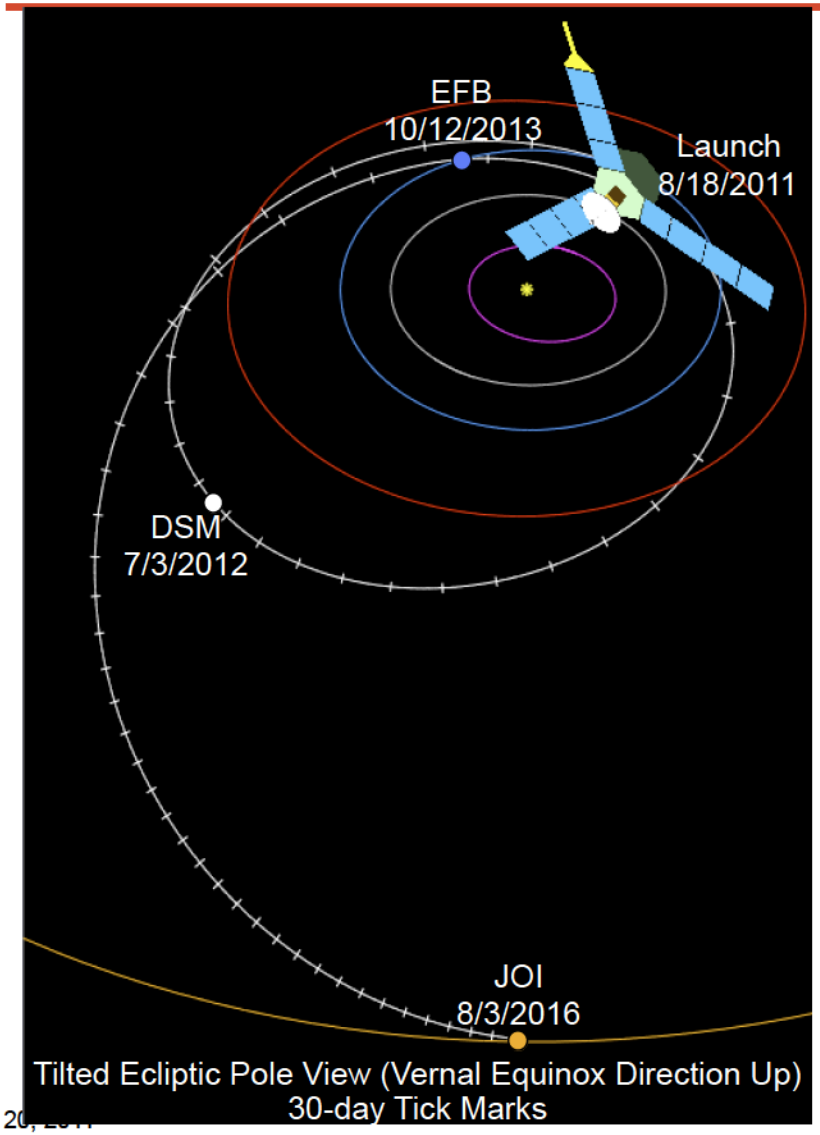
- Jupiter's Gravity Field
- Jupiter's Magnetic Field
- Deep Atmosphere
- Aurora/Magnetosphere





Gravity Science-GS (JPL, ASI)
Magnetometer— MAG (GSFC)
Microwave Radiometer— MWR (JPL)
Jupiter Energetic Particle Detector Instrument—JEDI (APL)
Jovian Auroral Distributions
Experiment— JADE (SwRI)
Plasma Waves Instrument- Waves (U of Iowa)
Ultraviolet Spectrograph— UVS (SwRI)
Jovian InfraRed Auroral Mapper - JIRAM (ASI)
Visible Camera - JunoCam (MSSS)

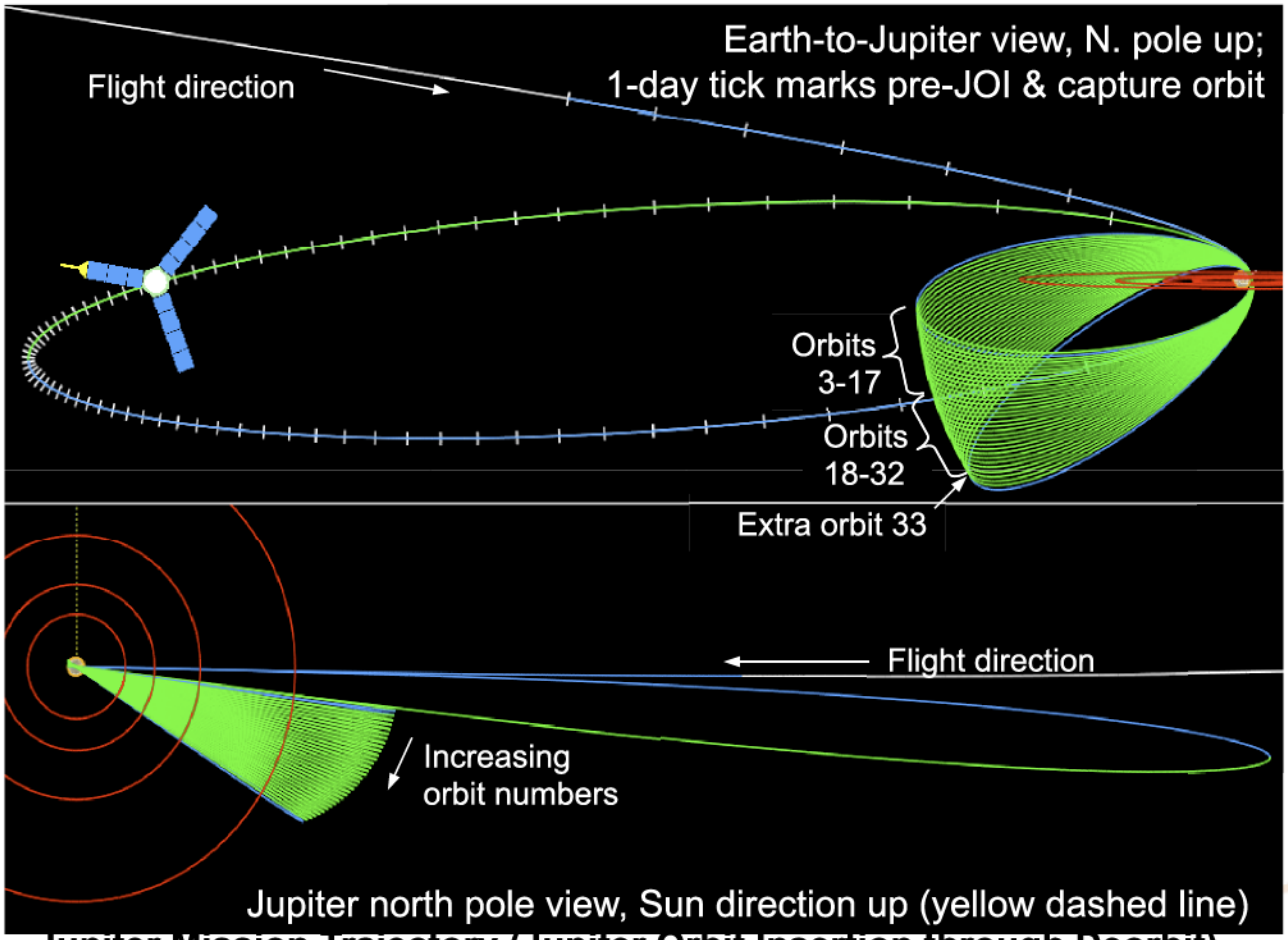
Interplanetary Trajectory



- ΔV-EGA (Delta-V, Earth Gravity Assist)
- Deep Space Maneuvers (DSMs)
  - 2 main engine burns, 33 minutes each
  - Target for Earth flyby
- Rehearsal for Jupiter Orbit Insertion (JOI)
- Earth flyby in October, 2013
  - 800 km altitude
  - Rehearsal for Jupiter perijove science
- Jupiter arrival 8/3/16, Launch + 5 yrs

Establishing Jupiter Science Orbit

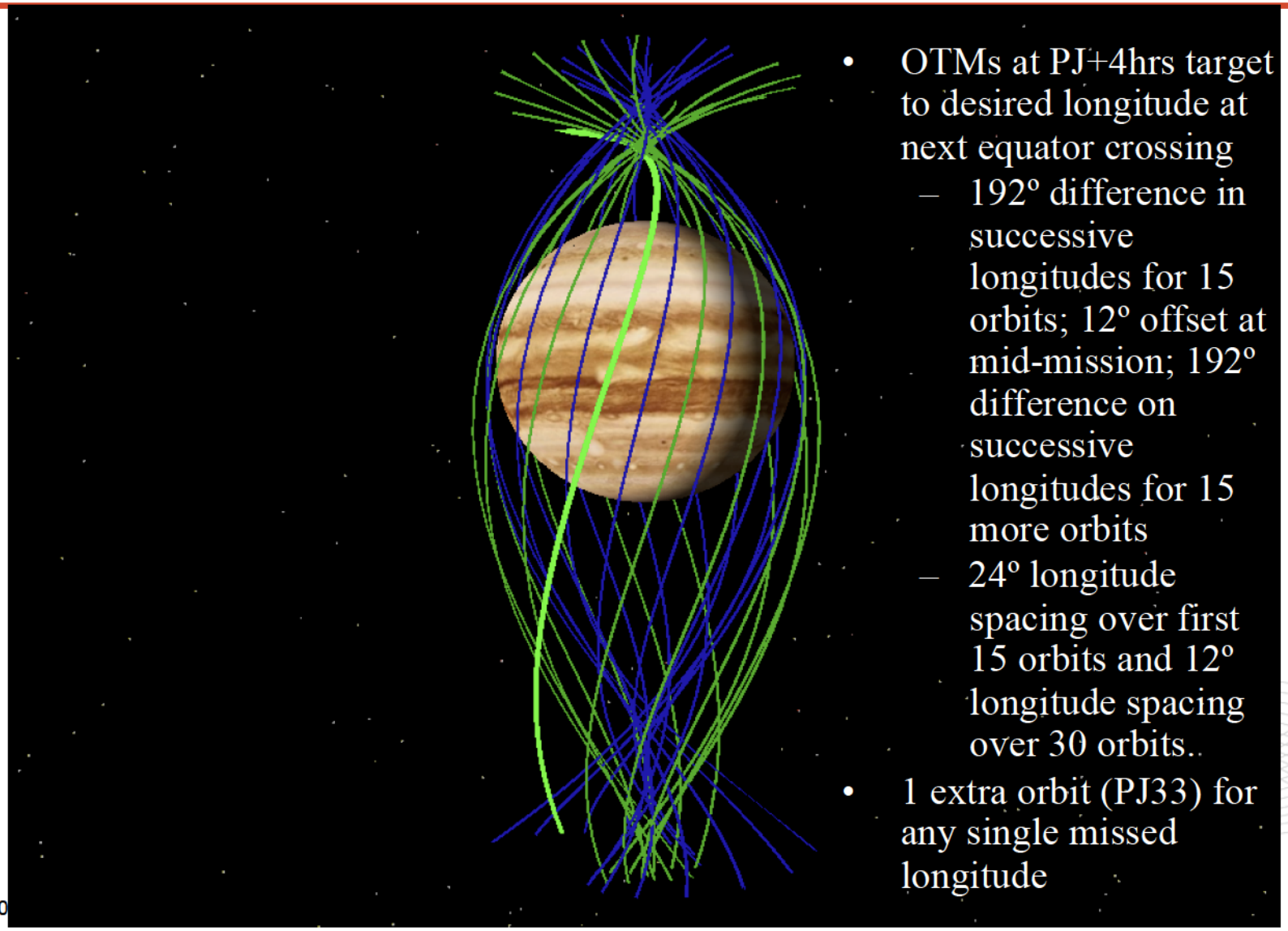
JOI phase in blue; orbit 1 in green; orbit 2 in blue; science orbits in green; deorbit phase in blue



Jupiter Mission Trajectory (Jupiter Orbit Insertion through Deorbit). Credits: Mission system

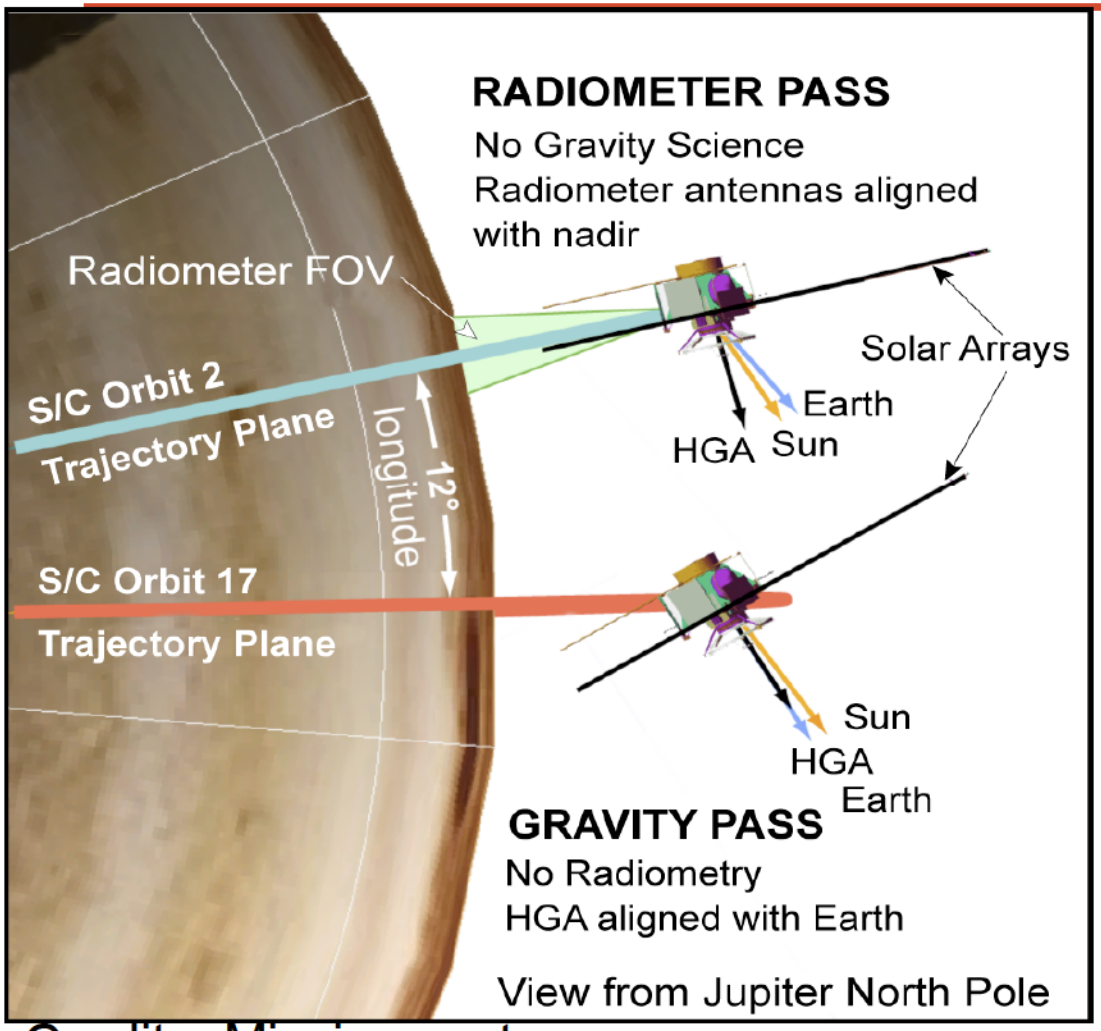
- JOI on 8/3/16
  - Main engine, toroidal antenna
  - ~ 30 min duration
- 78-day capture orbit
- Period reduction maneuver (PRM) occurs at PJ1
  - Main engine, toroidal antenna
  - ~30 min duration
  - Establishes 10.9725 day science orbit period
- 1st science perijove at PJ3 with final PRM cleanup at PJ3+4hrs.

Jupiter Mission Longitude "Web"



- OTMs at PJ+4hrs target to desired longitude at next equator crossing
  - 192º difference in successive longitudes for 15 orbits; 12º offset at mid-mission; 192º difference on successive longitudes for 15 more orbits
  - 24º longitude spacing over first 15 orbits and 12º longitude spacing over 30 orbits..
- 1 extra orbit (PJ33) for any single missed longitude

Science Orbit Modes

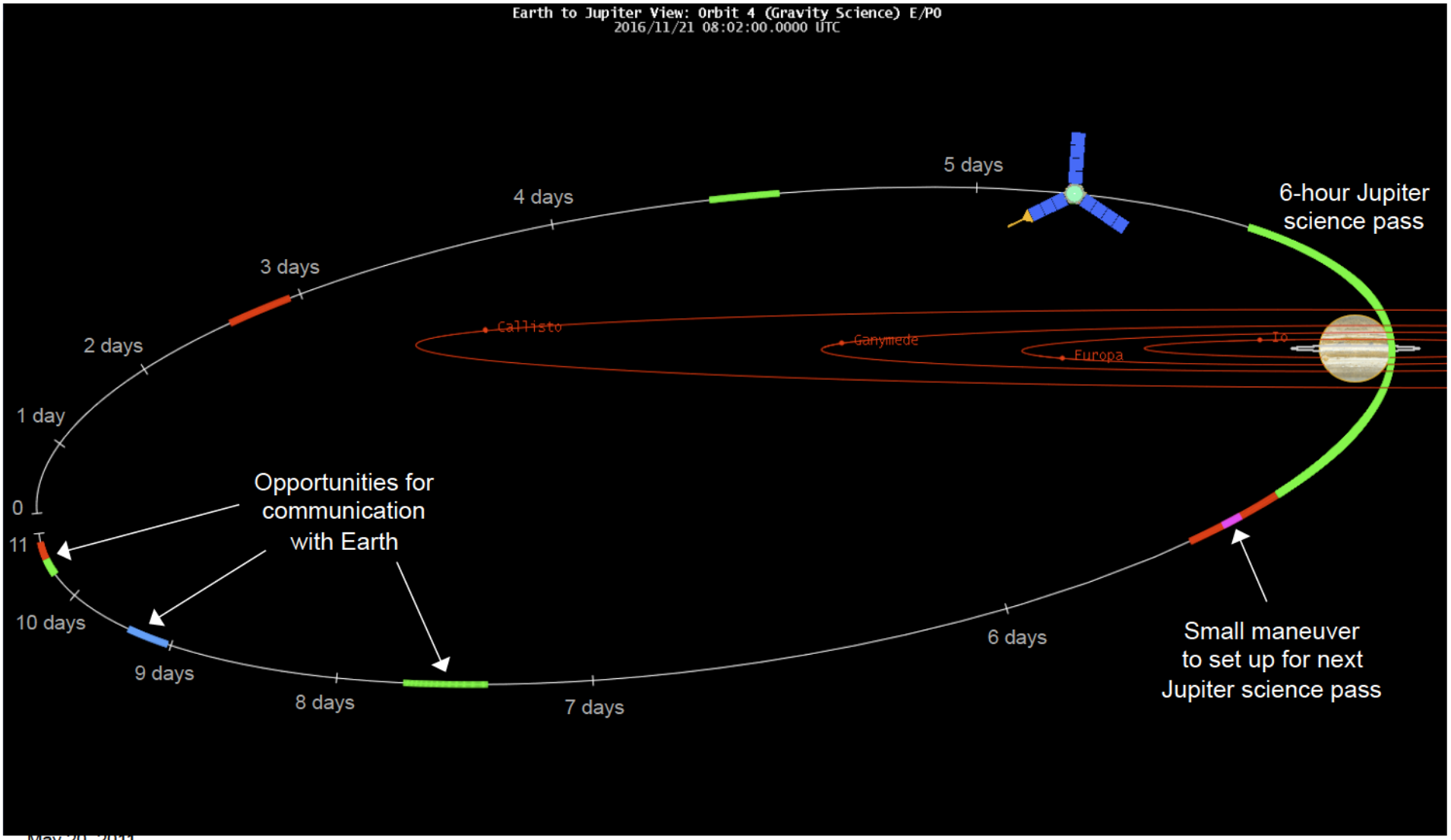


Credits: Mission system

Only two basic science modes for science orbits:

- Radiometer science mode
  - MWR, JIRAM, JunoCam are on
  - Gravity Science off
  - All other instruments on
- Gravity science mode
  - MWR, JIRAM, JunoCam are off
  - Gravity Science on
  - All other instruments on

Juno Orbit 4: Gravity Science



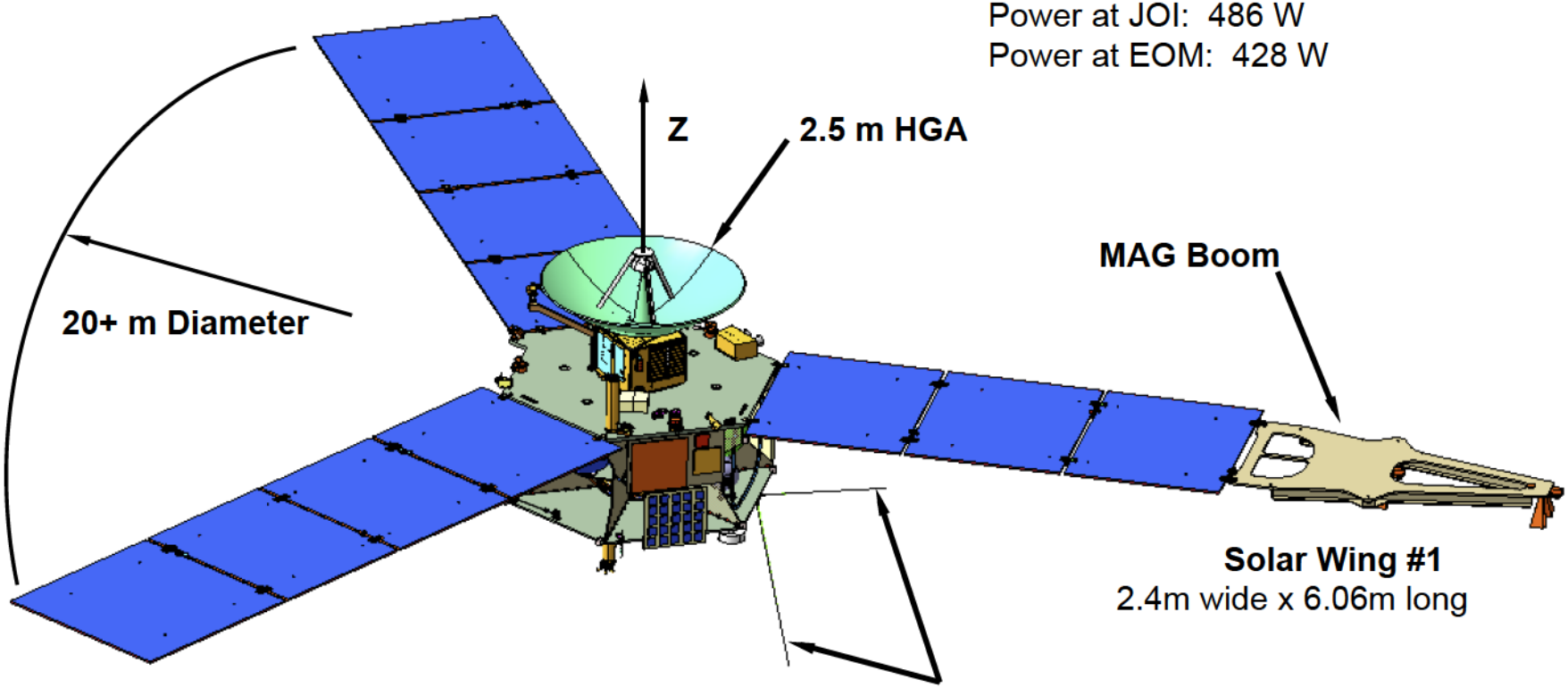
Credits: Mission system

Key Challenges

- Mission Design
  - Deep Space Maneuver
  - Earth Flyby
  - Jupiter Orbit Insertion
  - Jupiter De-orbit
  - Science Instrument Data Acquisition and Return
- Solar Powered Spacecraft at Jupiter
  - Operate between .876 Au and 5.46 Au
  - Solar incidence @ Jupiter approximately 3.3% of earth solar incidence
  - Account for radiation degradation
- Harsh Radiation Environment
  - Electronics vault for radiation protection
  - Sensor shielding
  - Spacecraft charging
  - Solar Array degradation
- Magnetic Environment
  - Spinning spacecraft in a high magnetic environment
  - Magnetic cleanliness for Magnetometer instrument

Juno Flight System

Power at 1 Au (theoretical): 15 kW
Power at JOI: 486 W
Power at EOM: 428 W

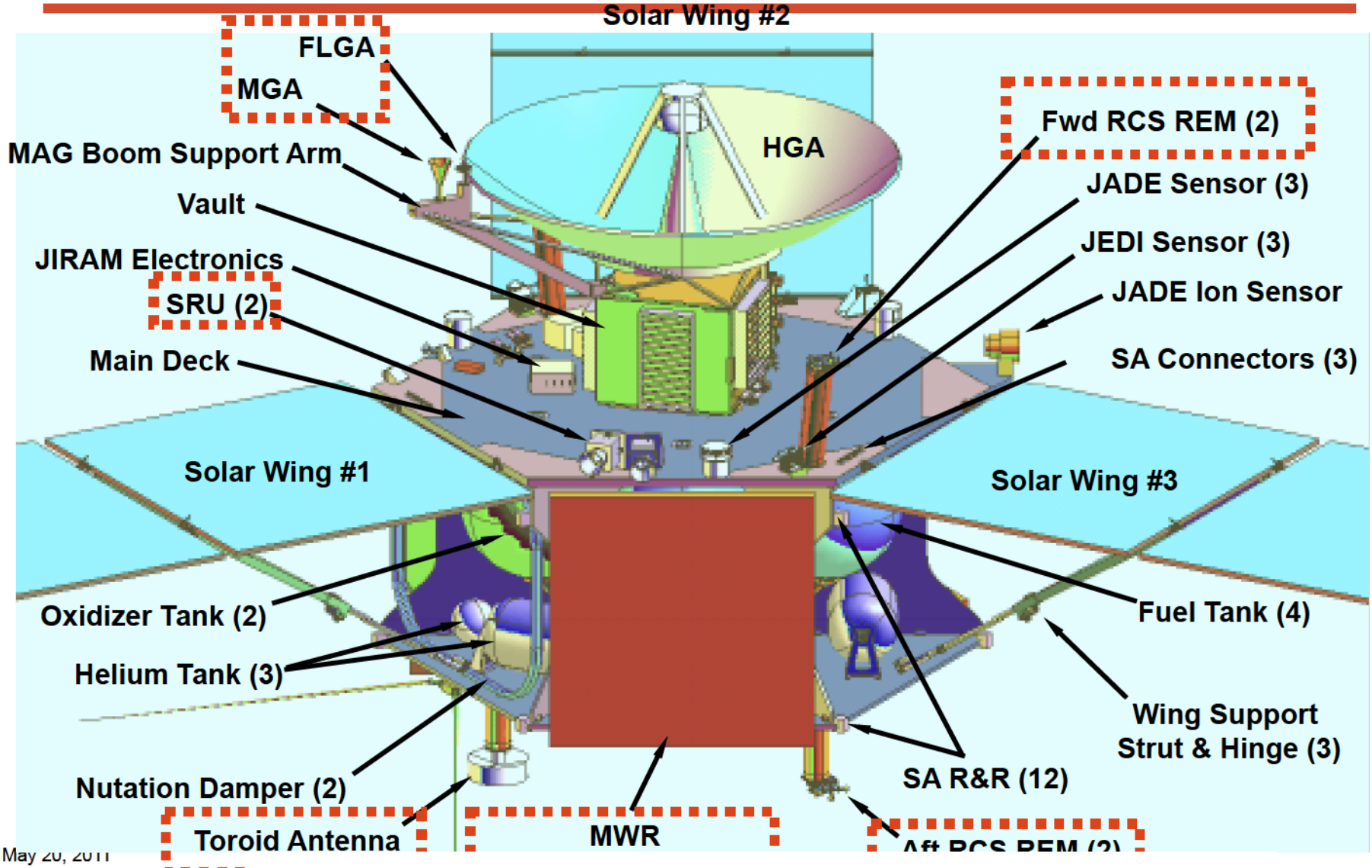


Flight System views courtesy of Lockheed-Martin

Spacecraft: ~1600 Kg dry mass; 3625 kg wet mass

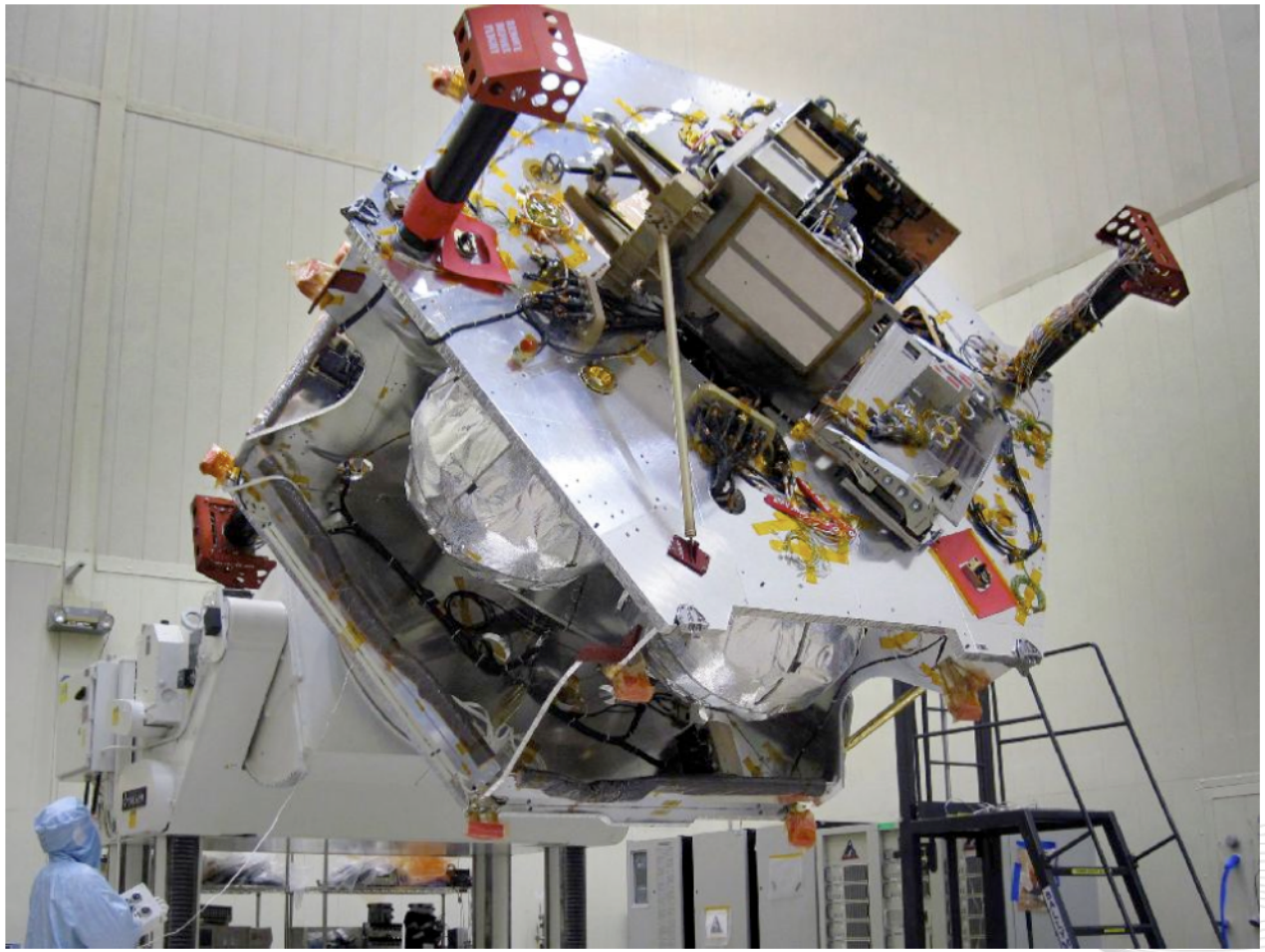
Matousek, S. Glasgow, Scotland, October 2, 2008, IAC-08-A3.6.11

+X +Y Bay Isometric



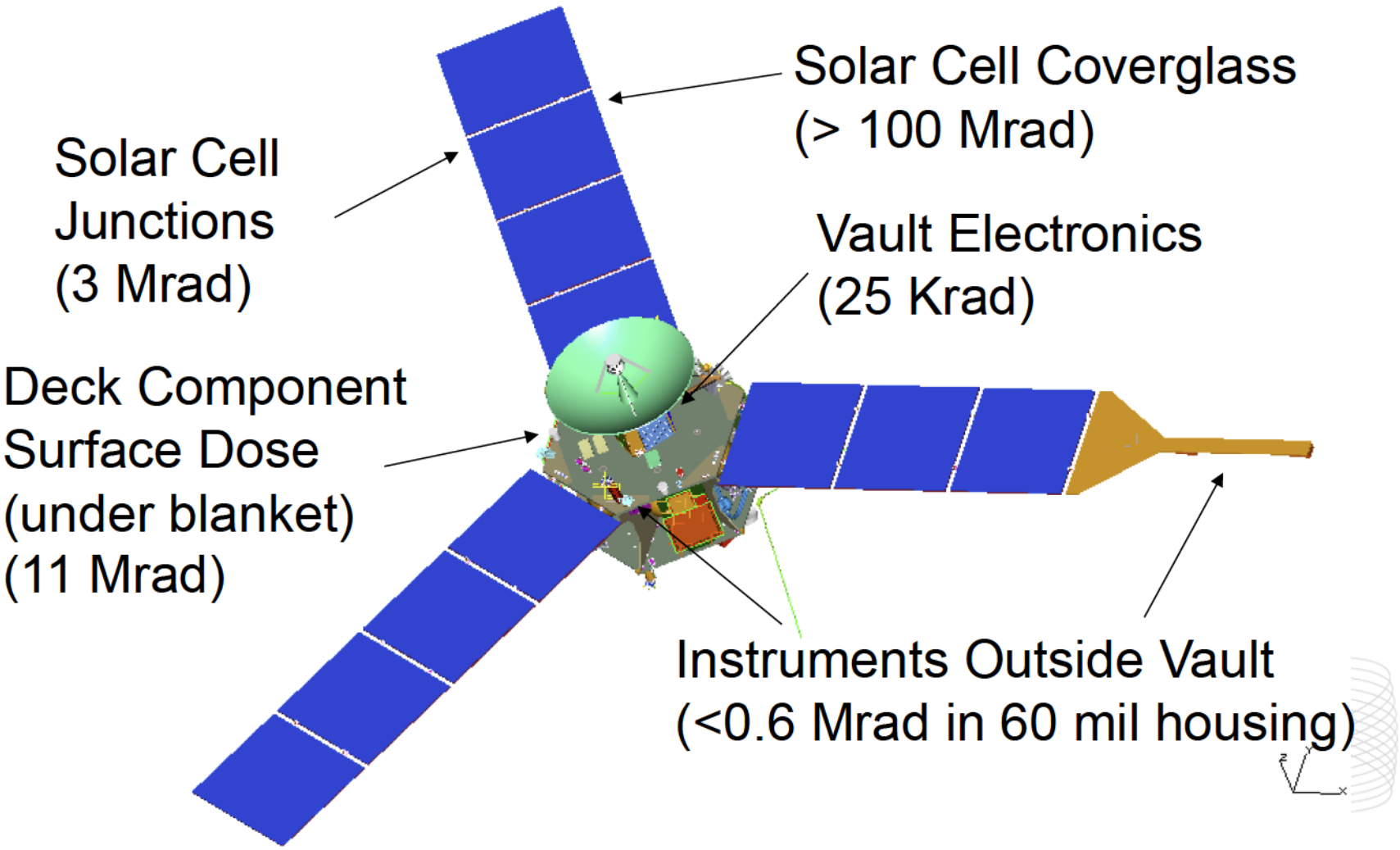
Matousek, S. Glasgow, Scotland, October 2, 2008, IAC-08-A3.6.11

The Juno spacecraft



Juno spacecraft at LMSS. Image credit: NASA/JPL-Caltech/LMSS.

End of Mission Radiation TID Levels

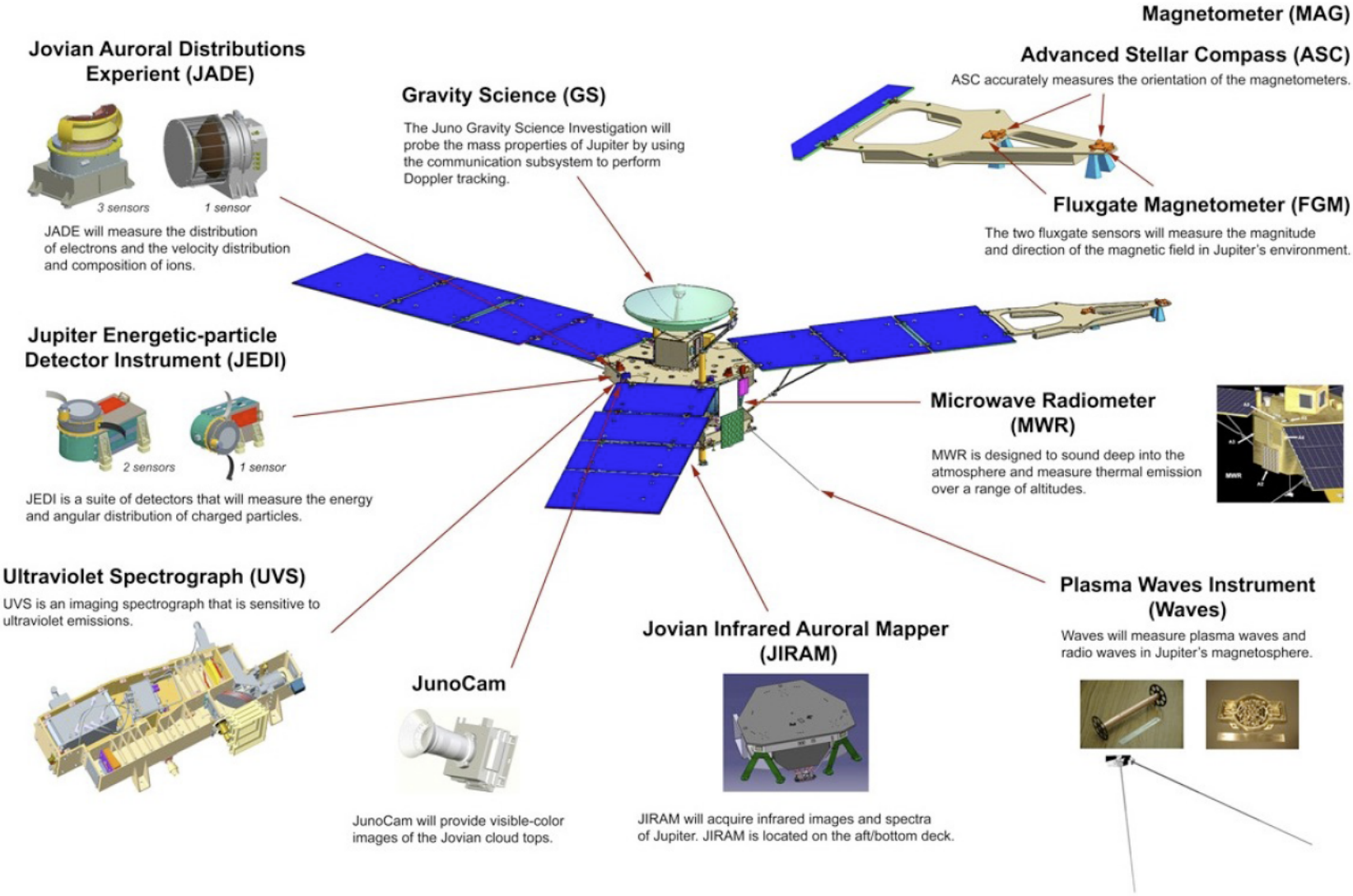


Matousek, S. Glasgow, Scotland, October 2, 2008, IAC-08-A3.6.11

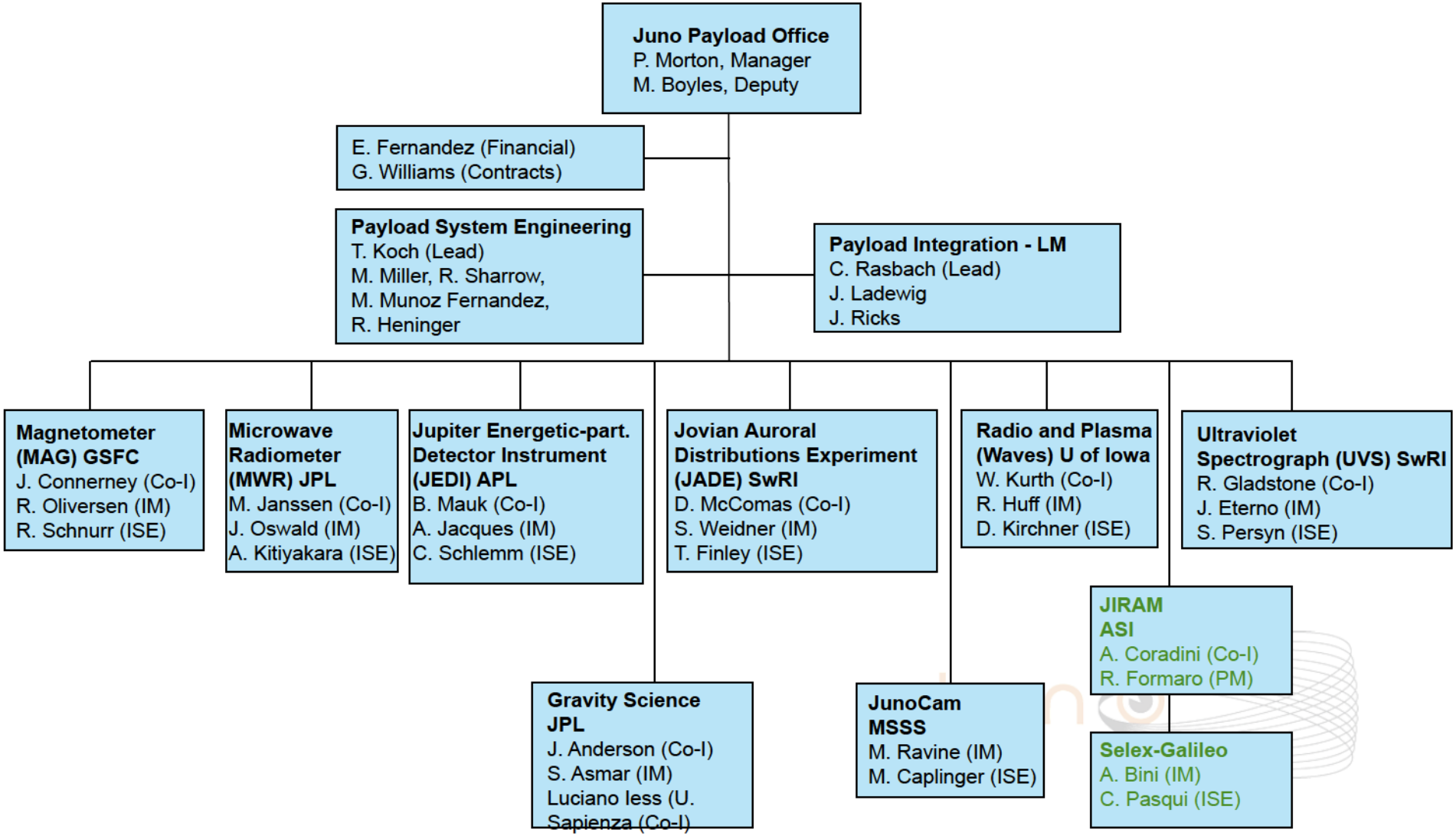
Payload System Overview

- Payload instruments directly map to Juno's science goals and objectives:
  - Characterize Jupiter's atmosphere
    - MWR, JPL
    - JIRAM, ASI
  - Map Jupiter's magnetic field
    - Fluxgate Magnetometer (FGM, GSFC)
  - Map Jupiter's gravitational field
    - Gravity Science instrument (X-band, JPL and Ka-band, ASI)
  - Characterize Jupiter's magnetosphere
    - JADE, SwRI
    - UVS, SwRI
    - JEDI, APL
    - Waves Univ. of Iowa
    - JIRAM, ASI
  - Engage the public and educate students
    - JunoCam (visible camera, MSSS)

Payload System: On Spacecraft



Payload System Organization



International collaboration on Juno

— The Juno mission is an example of excellence in international collaboration between NASA and ASI (Agenzia Spaziale Italiana).

-We have TAAs (Technical Assistance Agreement) in place: Primary Juno SWRI wide TAA: TA 0345-06E.

-Italian participation is based on its now established experience in the field of spectrometry, optical cameras and radio science.

-In particular, Italy has supplied two instruments: the infrared image spectrometer JIRAM (Jovian InfraRed Auroral Mapper, PI Angioletta Coradini INAF-IFSI, built by Selex-Galileo) and the radio science instrument KaT (Ka-Band Translator, PI Luciano Iess of the Università 'La Sapienza' of Rome, built by Thales Alenia Space-I) which constitutes the Ka band portion of the gravity experiment.

- Both of these instruments have taken advantage of important synergies with analogous instruments in development for ESA's BepiColombo mission, optimizing the costs, and increasing both the scientific and technological role of Italy.

International collaboration on Juno

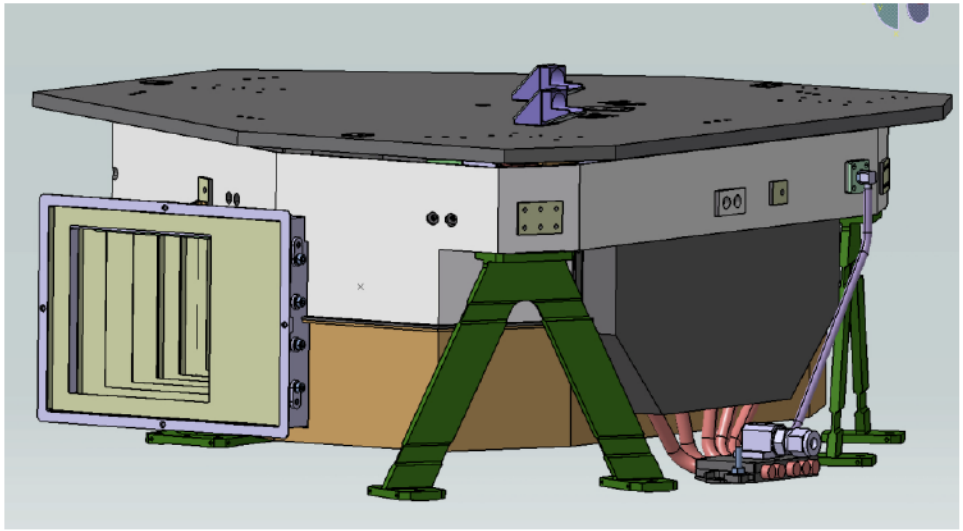
-In terms of science the instruments provided by ASI will enormously enrich the science data return from the Juno mission given their capabilities and scientific goals.

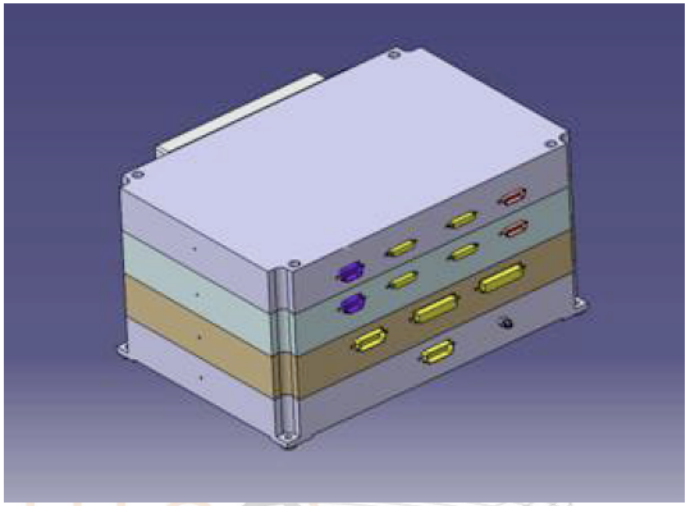
-Other international contributions to the Juno mission are the Danish Technical University (DTU), Denmark (Advanced Stellar Compass (ASC) providing accurate Juno spacecraft pointing needed for the magnetic and gravity field investigations is being fabricated by DTU), and Selex Galileo that provides the SRU for the Juno spacecraft.

Jiram architecture

JIRAM — Jovian InfraRed Auroral Mapper

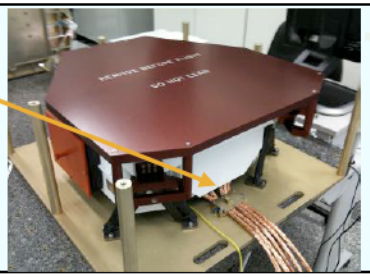
- **OM** — Optics Module
- **IUH** — Intra Unit Harnesses
- **ME** — Main Electronic





Intra Unit Harnesses

Optics Module



Main Electronic

JIRAM instrument-Optical Head

-

JIRAM Optical Head

JIRAM instrument-science

- The JIRAM instrument has a twofold objective:

- ***To perform imaging of Jupiter***, especially around the polar regions, in a the filters at 3.4 ±0.1 μm and 4.8 ±0.2 μm band, where the most of the aurora emission occurs

- ***To perform spectrometry*** of selected regions of the Jupiter's atmosphere in the 2-5 μm band with medium spectral resolution

JIRAM instrument science

-By means of its high contrast imaging and spectroscopy, JIRAM will study the dynamics and chemistry of auroral regions and their link to Jupiter's magnetic field and magnetosphere.

-JIRAM will image the auroras using wavelengths around 3.4 µm where the emission of the H_3^+ ion in the polar region is strong. This wavelength overlaps a deep methane absorption band.

JIRAM instrument science

-As a result, one can image Jupiter's ionosphere at this wavelength with a large signal-to-noise ratio against the planet, otherwise darkened by absorption due to methane in its atmosphere.

-H_3^+ is formed in the Jovian ionosphere by the (hydrogen) ion-molecule reaction ($H_2^+ + H_2 \longrightarrow H_3^+ + H$) that follows ionization of molecular H_2 by the charged particles falling on Jupiter and coupled with its strong magnetic field [JIRAM for Juno mission: retrieval capabilities for ammonia and water vapour in the hot spots. Davide Grassi, Angioletta Coradini, and Alberto Adriani, Geophysical Research Abstracts. Vol. 12, EGU2010-8653, 2010].

Payload System Engineering

Author's main line of work during the collaboration with the contribution of the Italian Space Agency:
-Instrument engineer for JIRAM during instrument development:

-Primary interface with the JIRAM team:
-Electrical, mechanical, thermal I/F
-Support the JIRAM team in all project reviews
-Special support for months before delivery
-Worked with the JIRAM team and LM in the installation and electrical integration on the S/C

Payload System Engineering

Duties after instrument integration:

Support the JIRAM team and across the payload during the S/C system test program:

-EMC test

-S/C thermal vac test

Acquiring deep understanding of ops needs for the instrument.

Also support as Instrument Operations System Engineer:

-GDS interface for ATLO tests, especially downlink data flow

-Support at Cape Canaveral for instrument activities and launch campaign

JPL, JIRAM, and LM teams during instrument integration

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JPL, JIRAM, and LM teams during integration. Image credit: NASA/JPL-Caltech/LMSS.

Acknowledgments

-I would like to thank all the members of the Juno team (JPL, LM, SWRI, etc.,) that have facilitated this interface with an international partner such as the Italian Space Agency.

-I would also like to thank Dr. Angioleta Coradini, Alessandro Bini, and Roberto Formaro and their respective teams for hosting me at Selex Galileo during the last phase of the instrument development and letting me feel part of their teams as well so that we could all work efficiently together to accomplish a common goal- the successful delivery, installation and integration of the JIRAM instrument on the Juno spacecraft.

-Thanks to the JPL Juno payload and mission offices for offering me the opportunity to work in this amazing mission.

- The work described in this presentation was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.