JUNO

Scott Bolton – Juno Principal Investigator
In the beginning....

• Scientists believe our solar system started as a cloud of gas in our galaxy...

• This cloud was probably like other clouds that we see throughout our galaxy...

• Clouds are mostly hydrogen and helium, different from the stars or the “plasma” that makes up most of our Universe
The Orion Nebula

Hubble Space Telescope
Wide Field Planetary Camera 2
Pillars of Creation
The First Step...

• Somehow the spinning cloud collapsed and our Sun was born.

• Most of the tiny bit of leftovers became Jupiter

• and the leftovers of the leftovers became the rest
Present theories of solar system origin and evolution do not explain how Jupiter was enriched in heavy elements.

This is key to understanding how giant planets form, in our own and other planetary systems.

These heavy elements are the seeds for the Earth and life as we know it.
The Elements...

• The key to understanding where we came from and how we got here....

• Everything is made up of atoms...

• There are different kinds, and the comparison of our composition with that of the sun, the planets, and the universe is a major clue
Consider the solar system as a soup...
we need to figure out the recipe...
Why Jupiter is so Important

• It’s the largest planet.

• Probably formed first.

• Is very much like the Sun in composition.

• We lost Earth’s history, but not Jupiter’s.
Gravity Science
Does Jupiter have a core of heavy elements?
What initiated the formation of Jupiter? When?
What were the conditions in the proto-planetary nebula?

Water Abundance
How does the enrichment of Oxygen compare with the other heavy elements?
How did the planets get their heavy elements?
How did Earth’s get its oceans and volatiles?
Galileo probe descent
Galileo Probe Results

- Galileo results show similar enrichment in key elements, independent of volatility.
- Results imply Jupiter formed colder and/or further out than 5 AU.
- Solid material that enriched Jupiter was most abundant solid material in early solar system.
Water is key to understanding the formation of Jupiter.

Water $\rightarrow$ Oxygen
Juno’s 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 at all latitudes.

Magnetosphere
Characterize and explore the three-dimensional structure of Jupiter's polar magnetosphere and auroras.
**Juno Mission Overview**

**Salient Features:**
- First solar-powered mission to Jupiter
- Eight science instruments to conduct gravity, magnetic and atmospheric investigations, plus a camera for education and public outreach
- Spinning, polar orbiter spacecraft launched on August 5, 2011
  - 5-year cruise to Jupiter, arriving July 4 2016
  - 16 months of science operations at Jupiter, ending with de-orbit into Jupiter in February 2018
- Elliptical 14-day orbit swings below radiation belts to minimize radiation exposure
- 2nd mission in NASA’s New Frontiers Program

**Science Objective:** Improve our understanding of giant planet formation and evolution by studying Jupiter’s origin, interior structure, atmospheric composition and dynamics, and magnetosphere
Juno Mission Design

- 32 polar orbits around Jupiter
- Each orbit is 14 days long
- Closest Juno gets to Jupiter is 5000 km
- Spacecraft spins 2 rpm
- Solar-powered
**Education and Science**

- Students contribute to Juno science
  - Modeling the radiation environment
  - Providing context for Microwave Radiometer data
- Juno science lessons (in and out of the classroom)
- Juno scientists participate in GAVRT teacher training
- Juno scientists in the (GAVRT) classroom
- Future plans (Junocam)
Juno’s Microwave Radiometer measures thermal radiation from the atmosphere to as deep as 1000 atmospheres pressure (~500-600 km below the visible cloud tops).

Determines water and ammonia abundances in the atmosphere all over the planet.

Synchrotron radio emission from the radiation belts makes this kind of measurement impossible from far away on Earth.
Atmospheric Dynamics

Radiometry investigates atmospheric structure

Gravity investigates differential rotation
Probing Deep and Globally

- Helium-poor molecular hydrogen
- Metallic hydrogen?
- Meteorological layer
- Convective region
- Radiative zone?
- Ice/rock core?

Pressures:
- 2 Mbar
- 40 Mbar
- 100 Km
- 600 Km
- 1000 Km
- 1 bar
- 12 bars
- 100 bars
- 5000 bars
Precise Doppler measurements of spacecraft motion reveal the gravity field.

Tides provide further clues.

Tracking changes in Juno’s velocity reveals Jupiter’s gravity (and how the planet is arranged on the inside).
Jupiter’s magnetic field lets us probe deep inside the planet.

Juno’s polar orbit provides complete mapping of planet’s powerful magnetic field.
Exploring the Polar Magnetosphere

Jupiter’s magnetosphere near the planet’s poles is a completely unexplored region!

Juno’s investigation will provide new insights about how the planet’s enormous magnetic force field generates the aurora.
Spacecraft & Payload

Juno’s Science Instruments

Gravity Science and Magnetometers
- Study Jupiter’s deep structure by mapping the planet’s gravity field and magnetic field

Microwave Radiometer
- Probe Jupiter’s deep atmosphere and measure how much water (and hence oxygen) is there

JEDI, JADE and Waves
- Sample electric fields, plasma waves and particles around Jupiter to determine how the magnetic field is connected to the atmosphere, and especially the auroras (northern and southern lights)

UVS and JIRAM
- Using ultraviolet and infrared cameras, take images of the atmosphere and auroras, including chemical fingerprints of the gases present

JunoCam
- Take spectacular close-up, color images

Jovian Infrared Auroral Mapper (JIRAM)

Plasma Waves Instrument (WAVES)

Ultraviolet Spectrograph (UVS)

Gravity Science

SPACECRAFT DIMENSIONS
- Diameter: 20 meters (66 feet)
- Height: 4.5 meters (15 feet)
A well designed trajectory

• DSMs (Deep Space Maneuvers aka main engine firings)
  • Early characterization of engine performance
  • Reduces risk at JOI

• Earth Flyby
  • Provides gravity assist
  • Allows early “science pass” of planetary body

• 5 Year Cruise
  • Team gains significant operations experience
  • Allows time to prepare for rapid 14 day science orbit cadence and limited 16 month mission

Juno’s Flight Plan, or Trajectory

Approx. 5 months to JOI
Bill Nye Explains the Earth Flyby
• Successful Earth flyby completed on Oct. 9, 2013
• Multiple spacecraft instruments took data as a practice run for Jupiter
• Juno left the encounter with the necessary velocity and heading to reach Jupiter on July 4th, 2016
EFB – Earth/Moon Video
Earth Flyby – Hi Juno Video
Video – JOI/Orbit
Longitude Map after 32 (+1) Orbits

In science orbits # 4-35 (ignoring # 0-3 & 36-37), Orbit Trim Maneuvers result in evenly spaced longitude grids after:

- 4 perijoves (# 4-7) $\Rightarrow$ 90° grid
- 8 PJs (# 4-11) $\Rightarrow$ 45° grid
- 16 PJs (# 4-19) $\Rightarrow$ 22.5° grid
- 32 PJs (# 4-35) $\Rightarrow$ 11.25° grid

Additional longitude shifts occur after perijoves 7, 11, 15, 19, 23, 27, and 31.

Jupiter North Pole View
Radiation Vault Move

Moving the Titanium radiation vault (with some avionics already installed) over to the propulsion module.
Radiation Vault

- Houses Juno’s critical electronics
- Walls are solid titanium
  - 1/4” – 1/3” thick
  - Weight empty – 350 lbs or 160 kgs
- Protects electronics from Jupiter’s intense radiation
- Vault reduces radiation levels by a factor of 800:1
- Allows use of electronics designs from previous NASA missions
Continued integration activities focusing on harness installation and test.
Juno Transport to KSC via C-17

Juno being loaded into a C-17 Globemaster for transport to Kennedy Space Center (KSC)

Below – Arrival at KSC Shuttle Landing Facility

Photo credit: Stephen Clark/Spaceflight Now
Final Testing & Encapsulation

Left - Juno, fully assembled, being moved from rotation fixture to test stand for ME actuator functional test in Building 1 Highbay

Right – Juno Prior to Encapsulation in Building 9 HPF

Photo credit: NASA KSC Media
“Science In A Fishbowl”

JUNOCAM

Upload your images of Jupiter, comment on the images, and vote on what pictures JunoCam will take when it reaches Jupiter.

PLANNING
Upload your telescopic images and data of Jupiter to help the team plan the mission

DISCUSSION
Create and comment on points of interest in Jupiter’s atmosphere

VOTING
Vote on points of interest for JunoCam to capture during its orbit of Jupiter

PROCESSING
Browse other users’ processed images from JunoCam or download, process, and submit your own images.

GO TO PLANNING
COMING IN FALL
COMING IN 2016
COMING IN 2016

PLANING

We’re calling all amateur astronomers to upload their telescopic images and data of Jupiter. These uploads are critical for the upcoming Discussion section (coming this fall) and will help NASA successfully plan the future of the mission.

missionjuno.swri.edu
click on “Junocam”
Products

The following products will be available for Jupiter arrival:

• NASA TV live broadcast – details coming soon!
• Jupiter Lithograph, Fact Sheet, Sticker
• Jupiter Teachable Moments
• Juno Models, including DIY online
• Juno solar power infographic
• Juno overview video
• “What’s Up” Juno-themed astronomy video
Fly Along with Juno

Juno is part of NASA’s 3D interactive, *Eyes on the Solar System*...

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For More Information...

Juno mission website: missionjuno.swri.edu

On the NASA website: www.nasa.gov/juno