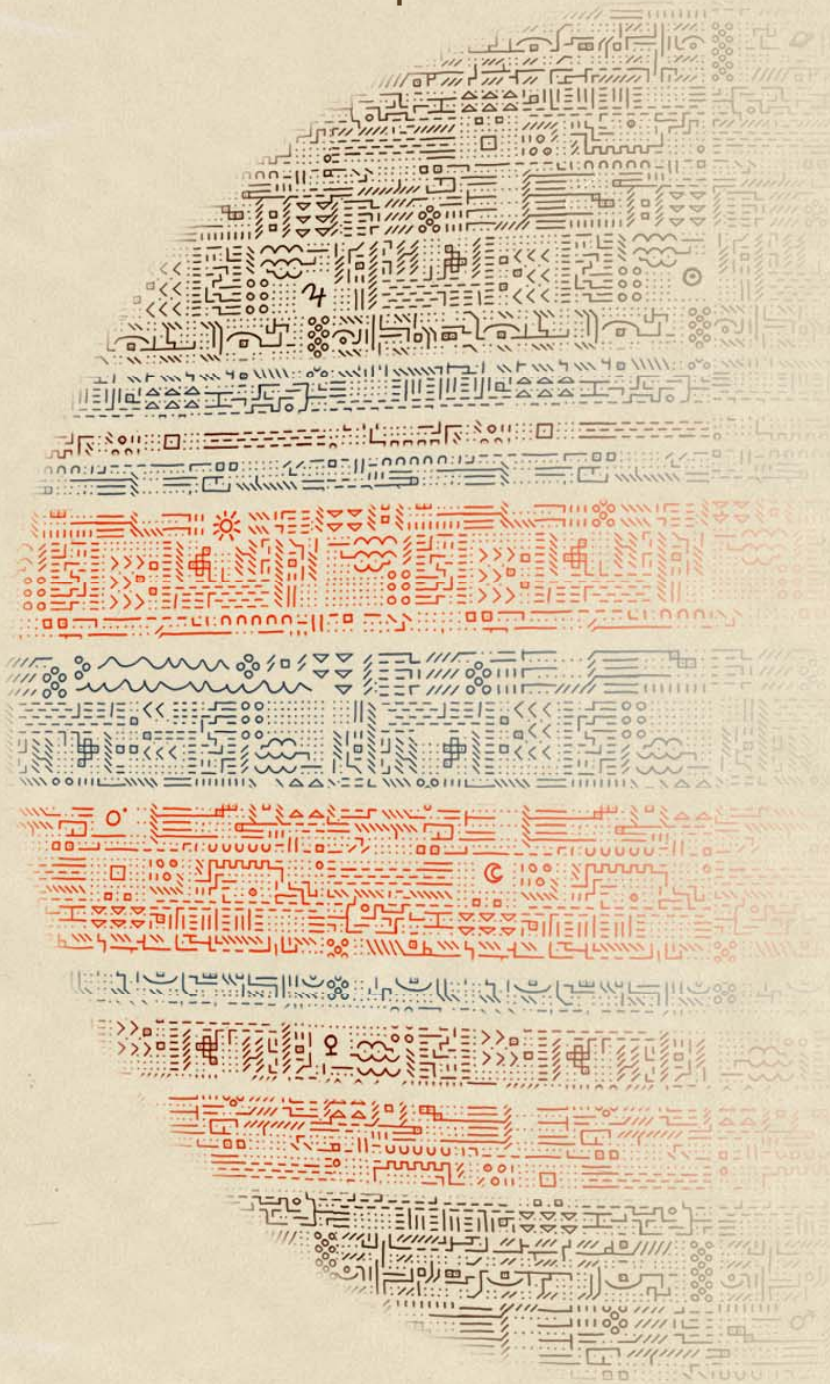
National Aeronautics and Space Administration



Microwave Radiometers from 0.6 to 22 GHz for Juno, A Polar Orbiter around Jupiter

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2008 IEEE Aerospace Conference
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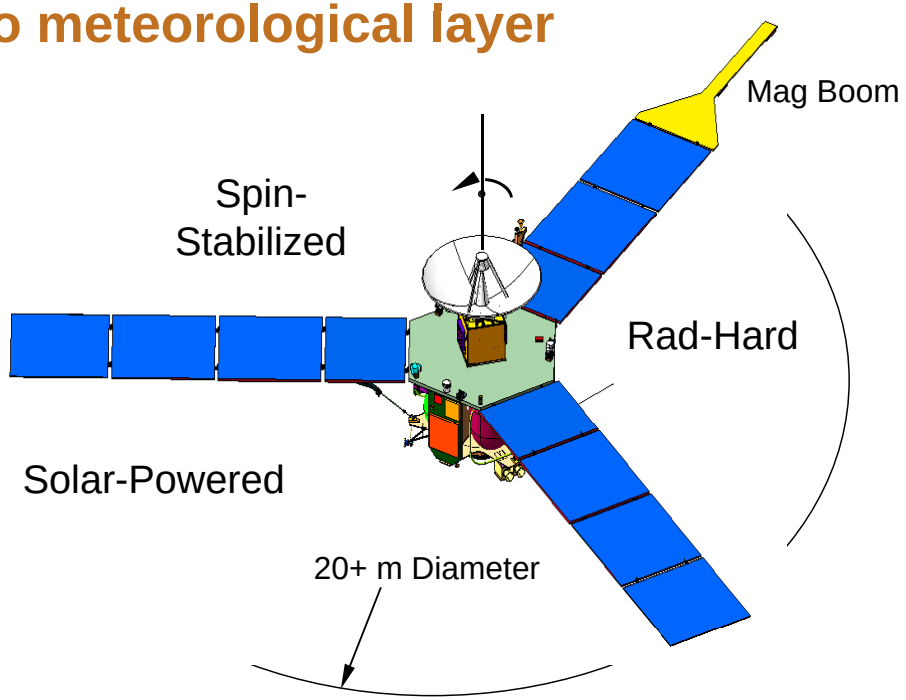
Proposed Juno Mission

Mission Timeline:

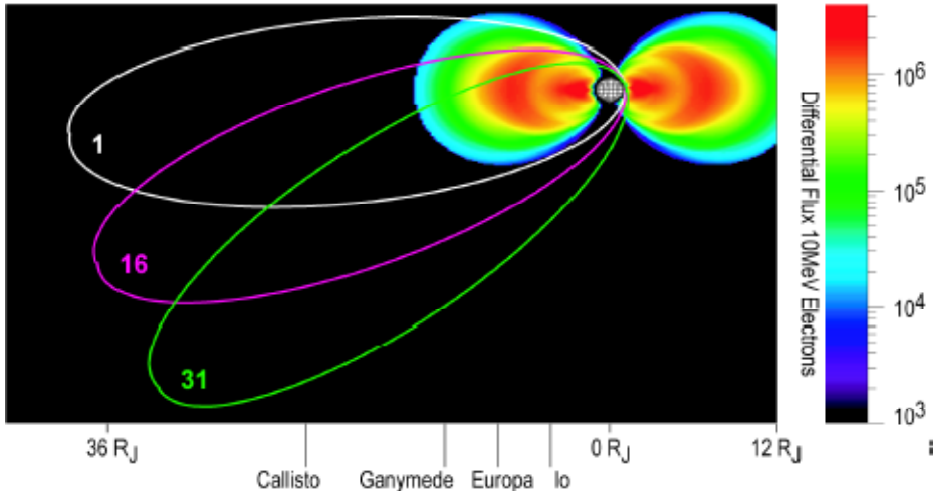
- May 2005 — Juno Selected
- Jan 2006 — Phase B start
- August 2011 — Launch
- October 2013 — Earth Flyby
- August 2016 — Jupiter Arrival
- October 2017 — Mission End
- 2017-2018 — Data Analysis

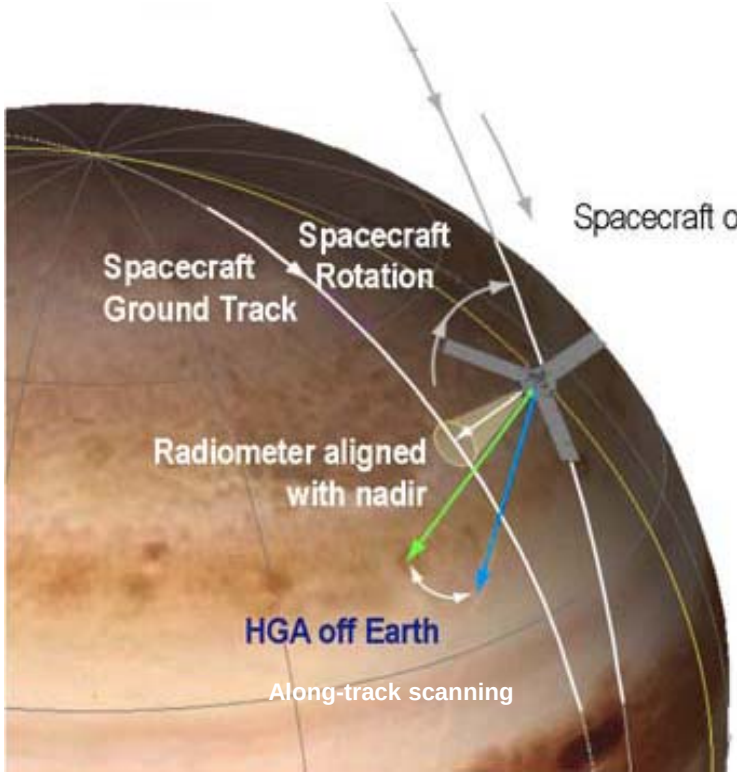
- **Gravity Science - gravity fields probe into central core region**
- **Magnetic Field Investigation (Magnetometers and star camera) - magnetic fields probe into dynamo region of metallic hydrogen layer**
- **Microwave Radiometer (MWR) - radiometry probes deep into meteorological layer**
- **Polar Magnetospheric Suite - 5 instruments**
- **Junocam - optical camera for Educational & Public Outreach**



Juno Science Observations

- **Highly elliptical orbits around Jupiter would avoid much of radiation belts**

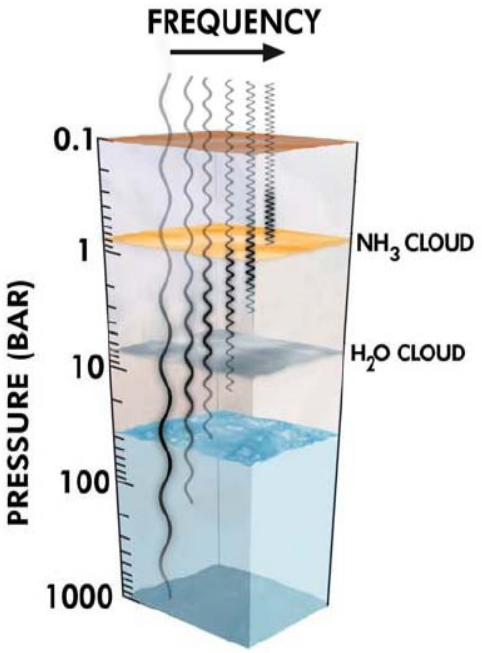


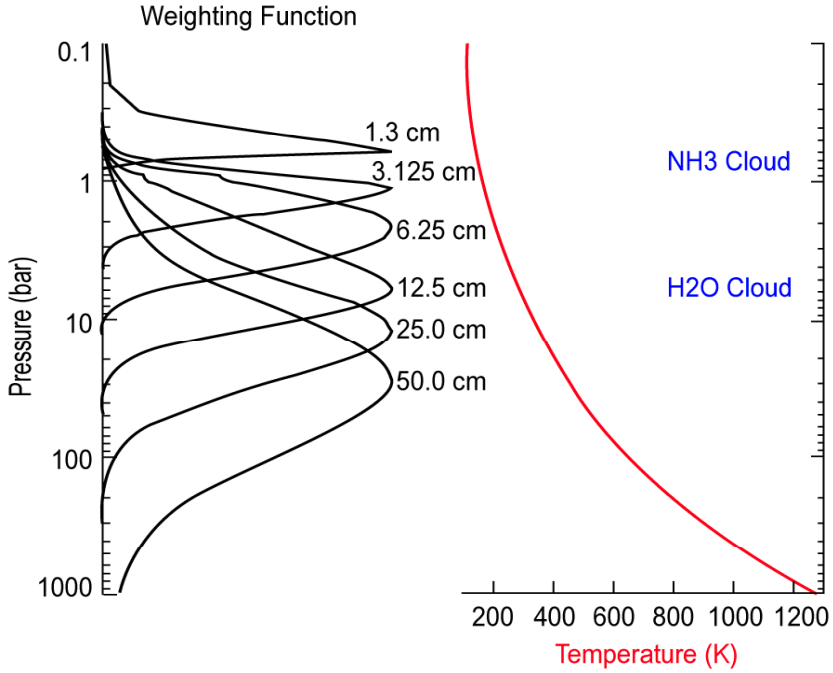


- **Unique microwave measurements would be obtained**
  - Synchrotron emission avoided
  - High spatial resolution obtained
  - Emission angle dependence uniquely measured by along-track scanning

Microwave Radiometry

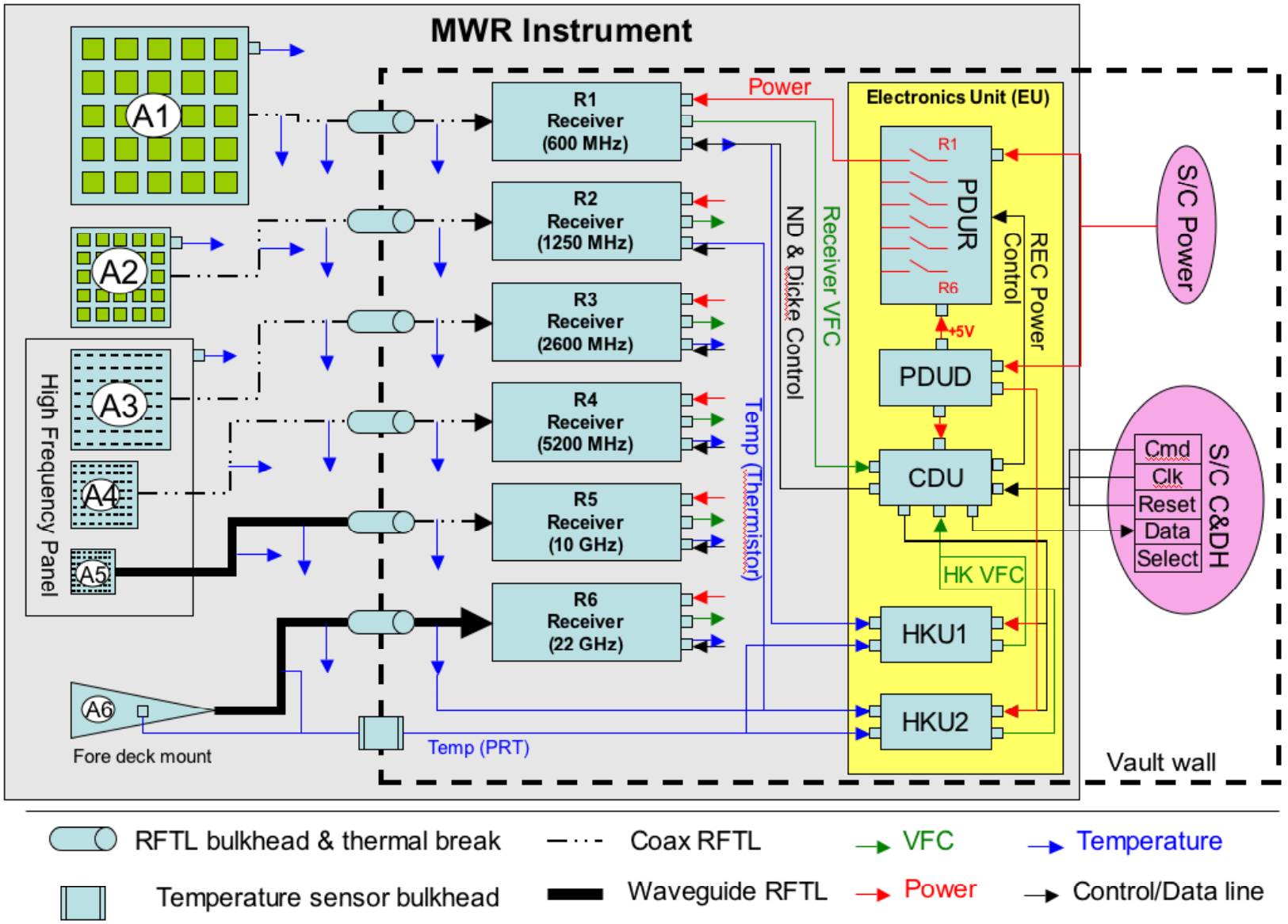
- **Radiometry sounds atmosphere to 1000-bar depth**
- **Determines water and ammonia global abundances**
- **6 wavelengths between 1.3 and 50 cm**





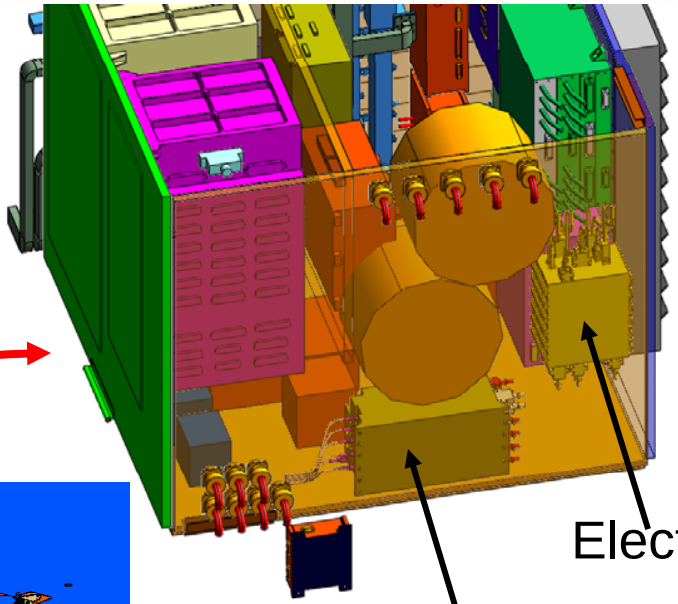
- **Microwave sounding would address 2 key questions:**
  - How did Jupiter form?
  - How deep are the atmospheric circulations?

MWR Instrument Block Diagram

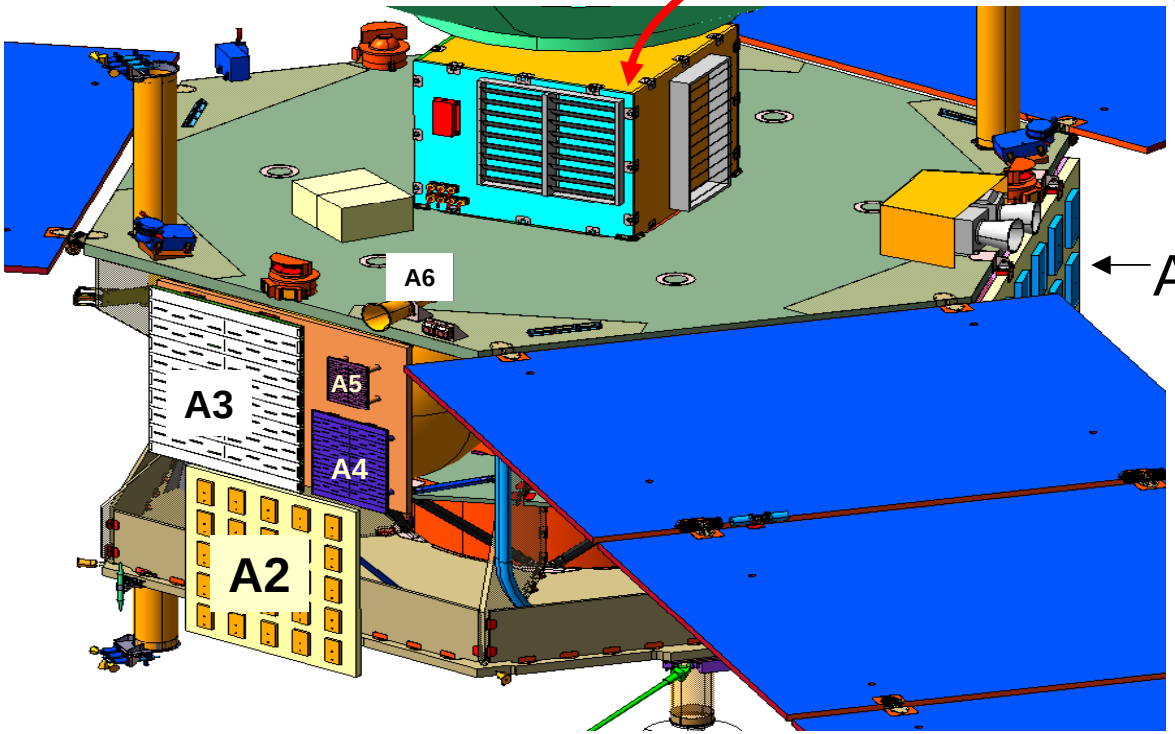


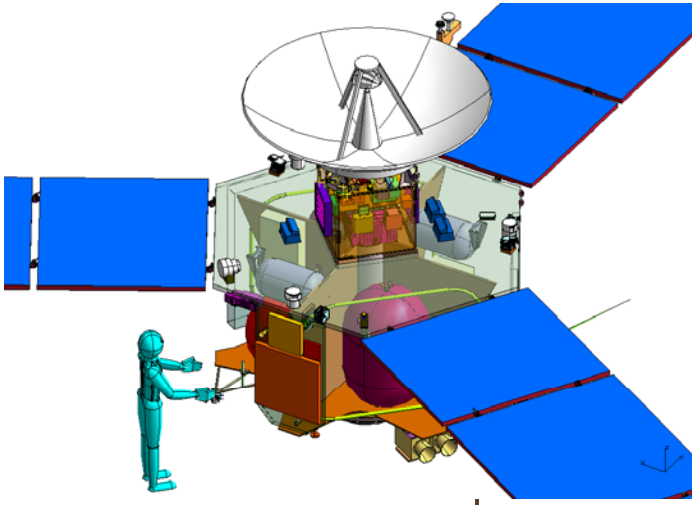
Spacecraft Accommodation of MWR

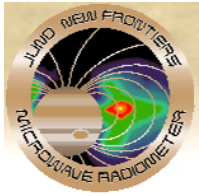
MWR System Allocations
Mass: 46 Kg
Power: 32 W



Radiation shielded vault



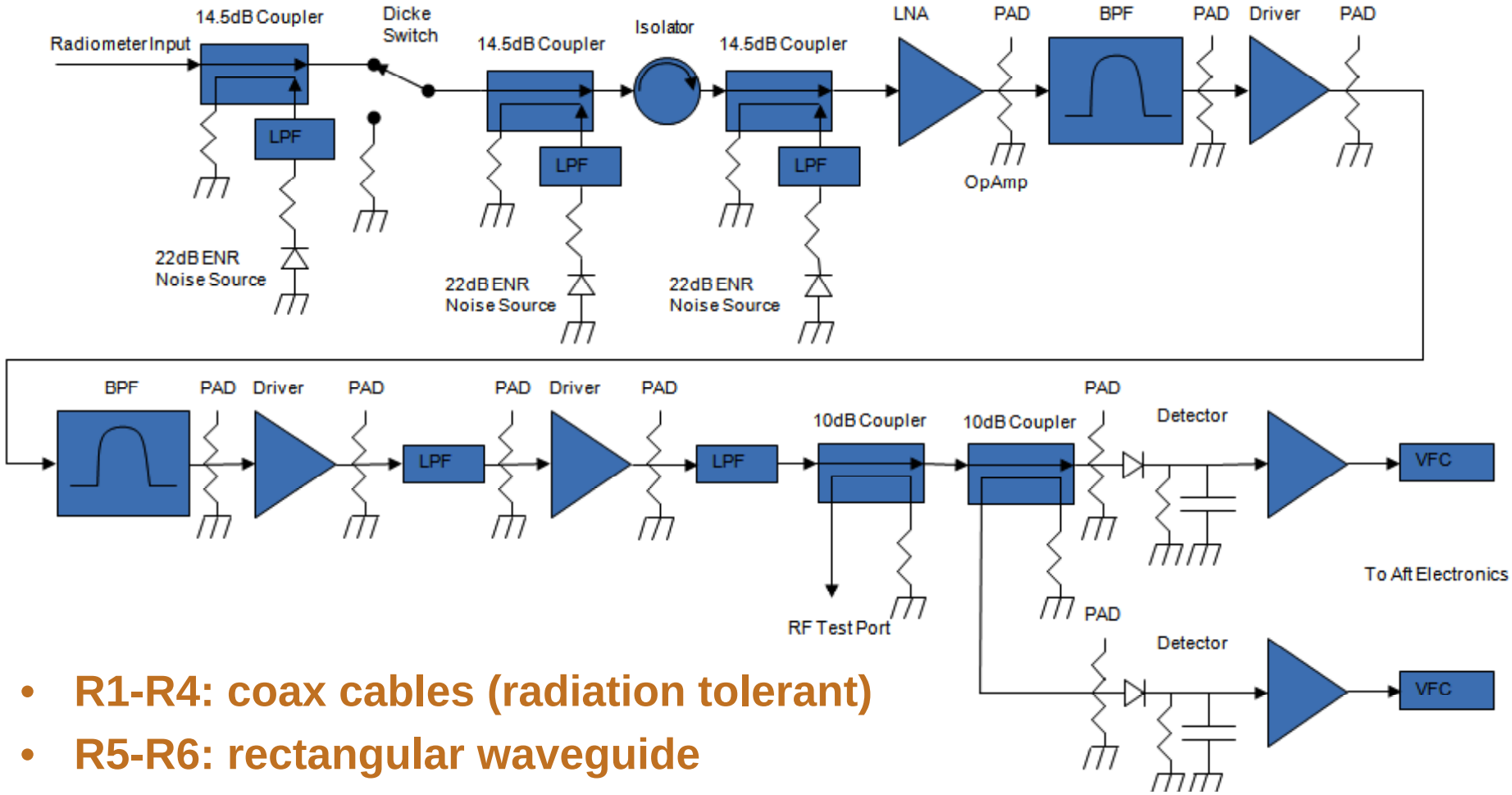




Calibration

- **MWR internal calibration system in each receiver front-end**
  - Precision noise diodes inject a stable noise signal and provide an estimate of radiometer gain
  - Internal Dicke switch between antenna and a 50-ohm ambient load
- **Internal calibration sources must be referenced to the input of the antenna**
  - References calibrated during pre-launch Thermal-Vacuum testing
- **Sensitive MWR receivers in radiation-shielded vault are 2-3 meters from MWR antennas**
  - Long RF transmission lines contribute 1-2 dB of loss
  - Large thermal gradient (~160 deg C) further complicates interactions

Receiver Block Diagram

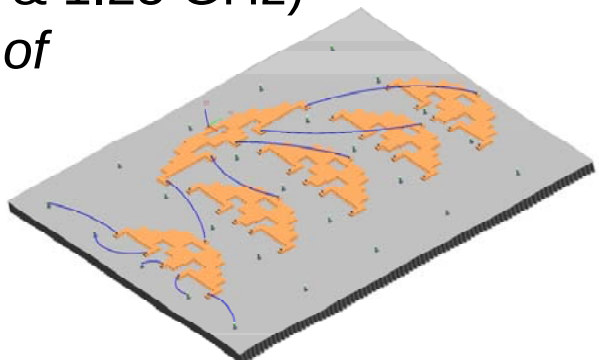


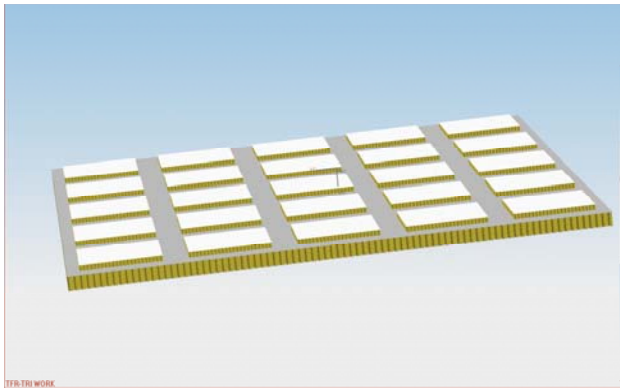
- **R1-R4: coax cables (radiation tolerant)**
- **R5-R6: rectangular waveguide**
- **Both phase-stable over broad temperature range to support accurate calibration**

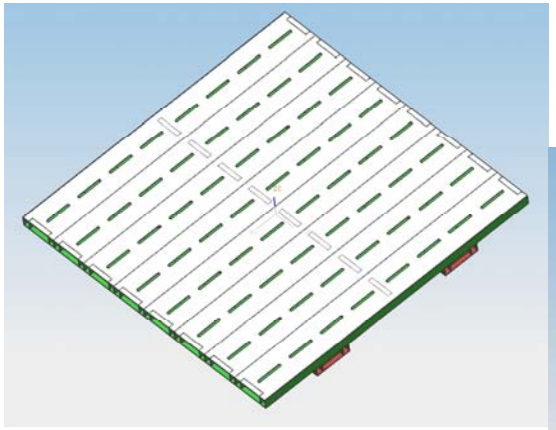
Antennas

A1/A2: Patch array (0.6 & 1.25 GHz)

Concept drawings of 5x5 patch array

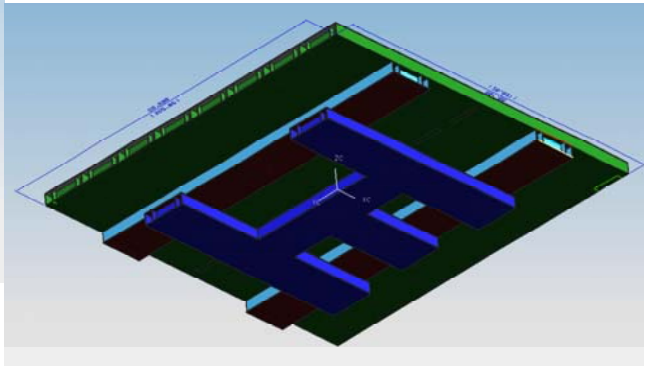


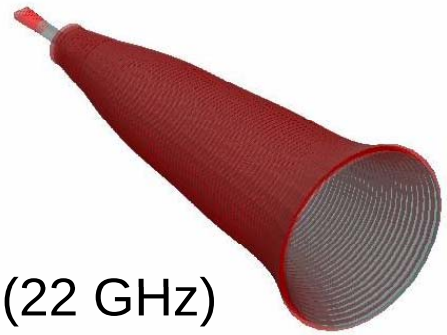




A3/A4/A5: Waveguide slot array (2.6, 5.2 & 10 GHz)

Concept drawings of 8x8 slot array





A6: Profiled corrugated horn (22 GHz)

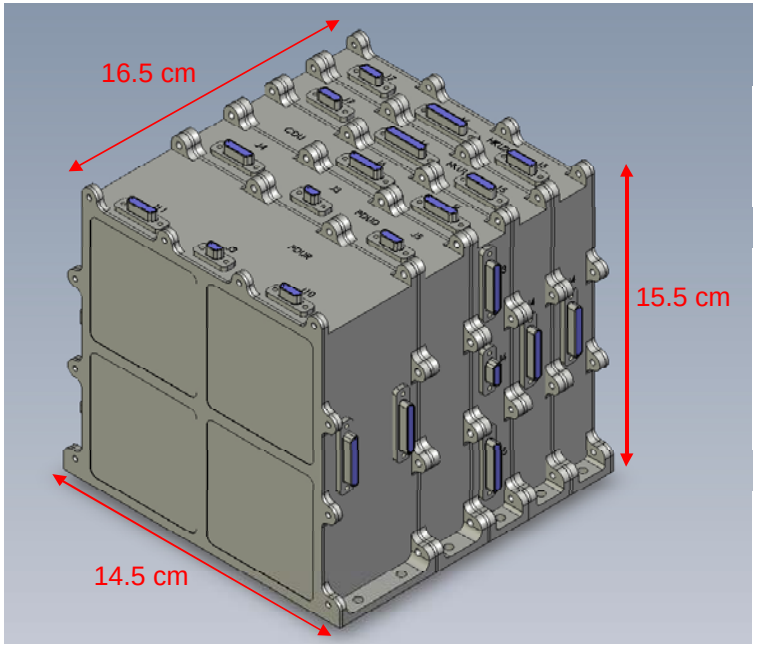
Concept drawing

Electronics

- **Power Distribution Units: PDUR (Receivers), PDUD (Digital)**
  - Redundant (A/B) converters
  - Receiver fault isolation

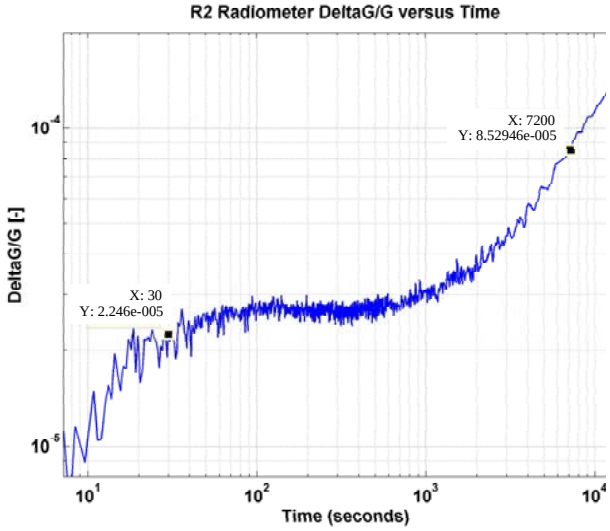
Converter	Interface	Function
+5V	CDU	Digital
+/-15V	HKU	Digital
+/-12V	R1-R6	Analog & Digital; 6 x VFC
+7V	R1-R6	RF on/off; Dicke switch
-5V	R1-R6	RF
+15V	R1-R6	RF; Noise Diode on/off

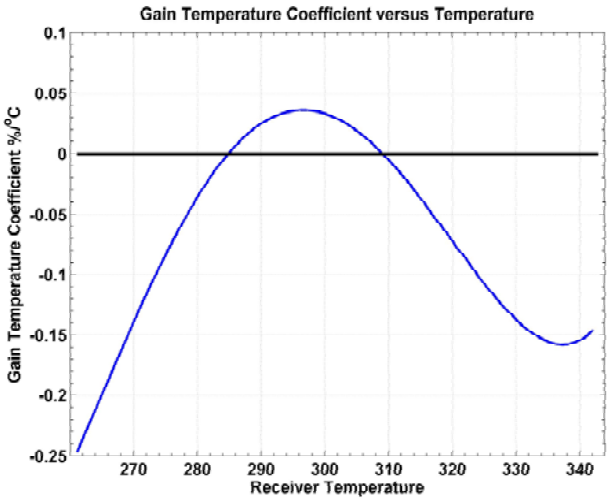
- **Command & Data Unit (CDU)**
  - RS-422 S/C Command & Telemetry I/F
  - 8051 microcontroller & FPGA provide Receiver control
  - Voltage-to-frequency converter (VFC) interface to Receivers and HKUs
- **Housekeeping Units (HKU1 & HKU2)**
  - Monitor 112 temps and 16 voltages
  - Thermistors inside the vault
  - Platinum resistive thermometers (PRTs outside the vault

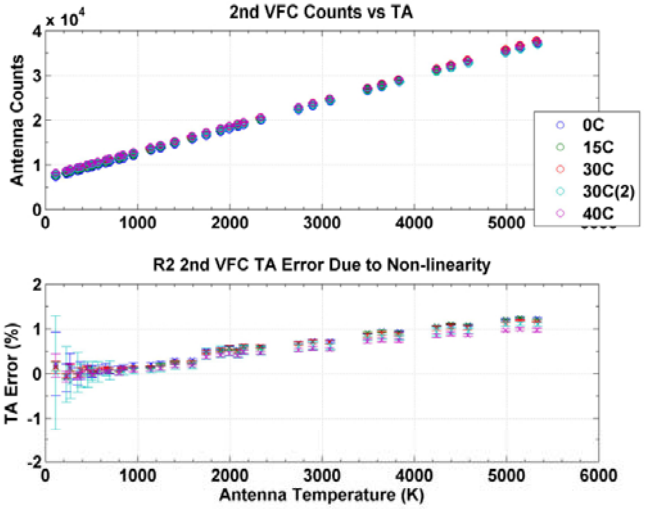


Initial Receiver Validation

- **R1/R2/R4 Breadboard Receiver Development**
  - LNA selection trades: noise performance, low-power consumption, gain, flight-qualification
  - H-frame chassis design separates DC electronics and RF for maximum noise rejection
- **Measured R2 (1.2 GHz) Performance**
  - Inherent gain stability, stability over temperature, radiometer linearity







Future Plans

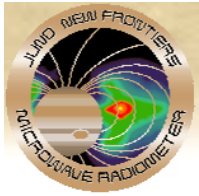
- **Pre-Launch**
  - Engineering Model (EM) subsystems would be developed in 2008 including integration in Instrument Test Bed
  - Flight Model (FM) subsystems would be developed and integrated in 2009 with extensive performance, calibration and environmental testing performed
  - MWR Instrument would be delivered to Lockheed Martin in Summer 2010 for integration onto Juno Spacecraft
- **Juno would launch in August 2011, 6-year journey to Jupiter**
- **Post JOI**
  - Juno would stabilize into 11-day, highly elliptical polar orbits
  - MWR would be operated for 5 of the first 8 orbits; vast majority of data required for a successful MWR experiment would be acquired in a single orbit

Summary

- **MWR instrument is a critical part of Juno Payload**
  - Six radiometric channels would allow global probing of the abundance and distribution of ammonia and water from the cloud tops to around 100 bars pressure for the first time
  - ➢ Satisfies a key objective of this NASA New Frontiers class mission

- **Antennas optimized for low side and back lobe levels over 4-pi steradians**
  - ➢ Critical feature for this experiment

- **Receivers are Dicke switched with built-in noise diodes**
  - In-flight characterization and calibration of the receivers
  - Achieve 0.1% relative brightness temperature measurement accuracy (the key & driving requirement for the instrument design)



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