EJSM-Submillimetre Wave Instrument

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Galileo Probe Temperature Profile

Young et al., JGR, 2005
Jupiter’s middle atmosphere

• Couples deeper tropospheric layers with the upper atmosphere

• Structure, circulation and composition poorly determined

• No cloud tracer, i.e. no direct wind measurements so far

• Ground-based observations and Voyager/Cassini provide:
  – temperature fields and thermal winds except around the equator
  – long term temperature variations (QQO)
CIRS temperatures and thermal winds

Flasar et al, 2004
• Meridional and vertical transport only little constrained by tracer observations after the SL-9 impact

• Future Herschel observations will provide new valuable data, however only on long transport time scales

• Waves seem to play a role in driving the circulation

• However role of mechanical and thermal forcing not clear, because no constraints of models by data

• Simultaneous temperature and direct wind measurement required
Submm Wave Instrument

• Vertical profiles of temperature

• Direct (Doppler) wind measurements

• Highly resolved 3-D monitoring of tracers:
  – SL-9 impact: CS, HCN, CO
  – external oxygen/water supply of uncertain origin

• Search for new molecules: CH$_3$OH, H$_2$CO, HC$_3$N, CH$_3$CCH
  halides (HCl…) …

• SWI observes in limb and nadir mode
Jupiter submm limb spectrum around 1200 GHz
1256 GHz Methane: wind and T retrieval simulation
VMR &T AKs of HCN, CS and CO
Atmospheres of Io & Europa

• 1000-1300 GHz: map SO$_2$/SO lines + isotopes and search for S$_2$O

• 400-500 GHz: map SO$_2$/SO/NaCl lines + isotopes and search for S$_2$O, OCS, KCl, ClO, SiO

• 557 GHz and 1097 GHz water observations (Europa)

• Relative importance of sputtering vs sublimation

• Inferior conjunction observations (5-10 points for antenna diameter 30 cm, 25-100 points for 60 cm aperture)
Ganymede: regolith studies

- Determine surface brightness temperatures in 600 and 1200 GHz bands with high spatial resolution

- Constrain amplitude and phase of thermal wave within the first centimeter of the regolith

- Determine thermo-physical properties of the regolith
Kick-off meeting 18-20 November

• Science review and refinement
• Observation strategy studies
• Instrument study progress:
  – Optical and receiver design
  – Mechanical design
  – Thermal design
  – Spectrometer design
  – Electronic Unit design
MIRO / Rosetta

SWI – ESA Study
Instrument characteristics

– Baseline

• Telescope D ~ 30 cm
  » Spatial resolution ~ 800 km @ 15 RJ distance
  » Vertical resolution: < ~ scale height

• Two spectral bands: 400-600 and 1080-1280 GHz

• Instantaneous bandwidth ~1 GHz, resolution ~200 kHz

• Tunable LO

• Uncooled Schottky receiver: $T_{sys}$ (DSB) ~6000 K at 1 THz, 2500 K at 500 GHz

Detection capabilities

1 min: line contrast ~ 0.6 – 1.65 K
1 hour: line contrast ~ 0.1 – 0.25 K

• Heritage: MIRO/Rosetta (in flight), MIME (proposed for Mars Express) + SWI (ESA-CDF study for Mars)

• ~10 kg, 48 W
SWI block diagram and responsibilities

![SWI Block Diagram](image-url)
## SWI M&P Budget

### Submm Instrument breakdown

<table>
<thead>
<tr>
<th></th>
<th>MIRO</th>
<th>SWI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dual channels; fixed tuned; fixed antenna; CTS backend</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass, kg</td>
<td>2.1</td>
<td>4</td>
</tr>
<tr>
<td>Pwr, W</td>
<td>0</td>
<td>8</td>
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<tr>
<td><strong>Detectors</strong></td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Pwr, W</td>
<td>20</td>
<td>16.4</td>
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<tr>
<td><strong>Backend</strong></td>
<td>5.8</td>
<td>1</td>
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<tr>
<td>Pwr, W</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td><strong>USO</strong></td>
<td>1.12</td>
<td>0.5</td>
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<tr>
<td>Pwr, W</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>Electronics</strong></td>
<td>5.87</td>
<td>4</td>
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<tr>
<td>Pwr, W</td>
<td>25</td>
<td>15</td>
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<tr>
<td><strong>Wiring</strong></td>
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<td>0.3</td>
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<tr>
<td>Pwr, W</td>
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<td>0</td>
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<tr>
<td><strong>Totals</strong></td>
<td>20.34</td>
<td>11.8</td>
</tr>
</tbody>
</table>

- **Mass** in kg
- **Power** in W

**Notes:**

- 30 cm primary ~ 1 kg, 3x for support
- Based on 2 separate RFES
- ASIC approach 400 MHz BW x2
- Non-redundant existing unit
- Based on FPGA approach, No bias for mixers etc, custom DC/DC
- Modular design
- Need to include MLI blankets, thermal hardware

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EJSM/SWI kickoff meeting, MPS, Nov 18-20, 2009
## Budgets

### Mass budget

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>primary mirror (Mg)</td>
<td>1020</td>
</tr>
<tr>
<td>actuator (ESA study)</td>
<td>1800</td>
</tr>
<tr>
<td>receivers (both)</td>
<td>280</td>
</tr>
<tr>
<td>spectrometers (CTS)</td>
<td>1500</td>
</tr>
<tr>
<td>electronics</td>
<td>1000</td>
</tr>
<tr>
<td>synthesizers</td>
<td>500</td>
</tr>
<tr>
<td>optics</td>
<td>500</td>
</tr>
<tr>
<td>structure</td>
<td>2910</td>
</tr>
<tr>
<td>cables, screws, mountings</td>
<td>1000</td>
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</table>

**Total:** 10.51 kg

### Power budget

<table>
<thead>
<tr>
<th>Component</th>
<th>Power (W)</th>
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<tbody>
<tr>
<td>actuator (ESA study)</td>
<td>5</td>
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<tr>
<td>receivers (both)</td>
<td>20</td>
</tr>
<tr>
<td>spectrometers (CTS)</td>
<td>10</td>
</tr>
<tr>
<td>control electronics</td>
<td>2</td>
</tr>
<tr>
<td>synthesizers</td>
<td>5</td>
</tr>
<tr>
<td>cal. mirror</td>
<td>2</td>
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</tbody>
</table>

**Sum:** 44 W

**DC/DC overhead (80% eff.)** 11 W

**Total:** 55 W
## Actual and predicted performances

![JPL logo](https://via.placeholder.com/150)

### Table of Performances

<table>
<thead>
<tr>
<th></th>
<th>600 SHM</th>
<th>600 SHM</th>
<th>600 FBM</th>
<th>600 FBM</th>
<th>1200 SHM</th>
<th>1200 SHM</th>
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</thead>
<tbody>
<tr>
<td>Tamb (K)</td>
<td>295</td>
<td>120</td>
<td>295</td>
<td>120</td>
<td>295</td>
<td>120</td>
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<tr>
<td>Tmix DSB range (K)</td>
<td>3000</td>
<td>1500</td>
<td>2000</td>
<td>1000</td>
<td>4000</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>4000</td>
<td>2000</td>
<td>3000</td>
<td>1500</td>
<td>5000</td>
<td>2500</td>
</tr>
<tr>
<td>CLmix DSB (dB)</td>
<td>10-12</td>
<td>10-12</td>
<td>7-8</td>
<td>7-8</td>
<td>12-14</td>
<td>12-14</td>
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<tr>
<td>LO power (mW)</td>
<td>3-5</td>
<td>3-5</td>
<td>1-2</td>
<td>1-2</td>
<td>3-5</td>
<td>3-5</td>
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<tr>
<td>IF band (GHz)</td>
<td></td>
<td></td>
<td>2-8 GHz</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>T_{IF} (K)</td>
<td>85</td>
<td>10</td>
<td>85</td>
<td>10</td>
<td>85</td>
<td>10</td>
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<tr>
<td>Trec DSB range (K)</td>
<td>3900</td>
<td>1600</td>
<td>2500</td>
<td>1050</td>
<td>5500</td>
<td>2200</td>
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<tr>
<td></td>
<td>5400</td>
<td>2150</td>
<td>3550</td>
<td>1600</td>
<td>7200</td>
<td>2750</td>
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<tr>
<td>Delta T (K) *</td>
<td>3.9-5.4</td>
<td>1.6-2.1</td>
<td>2.5-3.5</td>
<td>1-1.6</td>
<td>5.5-7.2</td>
<td>2.2-2.7</td>
</tr>
</tbody>
</table>

* B = 1 MHz, σ = 1 sec, and Trec assumed

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EJSM/SWI kickoff meeting, MPS, Nov18-20, 2009
Spectrometer: status reflective array compressor (Dispersive Delay Line, DDL)

Optimize the reflection coefficient by adjusting the groove depth to the reflective wavelength. Duty cycle weighting helps to optimize the bandpass characteristics (ratio of groove widths to groove distance)
Latest DDL results: IL=57 dB
Envelope of compressed pulse power
Heat transfer via:

- space craft mounting plate (ambient)
- optional radiator for ambient electronics and motor
- optional radiator for cooled receiver (0.036 m^2 ~ 0.6W @ 150K)
- optional heat pipe / thermal strap for cooled receiver
Thermal Design C – Distributed Receiver

**Instrument Level:**
- cooled receiver
  - $\sim 0.6\text{W} @ 50\text{K}$
- local oscillator
  - $\sim 20\text{W} @ 150\text{K} (300\text{K})$
- Nadir view
- scanning mech.
  - $\pm 90^\circ / \pm 4^\circ$
- opt. radiator
  - $\sim 0.036\text{m}^2$
- opt. heat pipe

**Common Shielded Electronic Vault:**
- synthesizer
- CTS Spectrometer
- TM/TC data & operation control
- Operation: 30W dissipation
- Stand-by: “collateral” heating
Next Steps

- Proceed with RTE/retrieval simulations
- Iterate with science requirements
- Evaluate observing scenarios vs mission phases
- Optimize two actuator optical design
- Proceed with thermal design
- Proceed on Electronics Unit
- Start radiation analysis
- Next team meeting end of February
Schedule of Phase-A Study

Kick-off meeting: 18-20 Nov. 2009
Upper stratosphere: HCN, CS & CO
1097 GHz H$_2$O & isotope: wind & T retrieval simulation