EO Sensors : ISRO
Past, Current & Future

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Karunya University, Coimbatore, 10 Jan 2013
Historical Development

• Aryabhatta
  – First Satellite (Not EO) built by ISRO & launched from Russia

• Bhaskara I (1979) & Bhaskara II (1981)
  – First series of experimental Earth Observation satellites,

• Geostationary for Weather Studies

• Experimental & Technology Satellites
  – SROSS, TES (High Resolution), IMS (Microsatellite)

• Operational IRS Series
  – IRS 1A, IRS 1B, IRS 1C, IRS 1D

• Thematic Series
Bhaskara satellite

• Bhaskara I
  – Launched: June 7, 1979 by Intercosmos (USSR)
  – Optical: TV Camera, 1 km, 2 band (Red, NIR)
  – Microwave Radiometer: SAMIR (19.24, 22.235, 31.4 GHz)

• Bhaskara II
  – Launched: Nov 20, 1981 by Intercosmos (USSR)
  – Optical: TV Camera, 1 km, 2 band (Red, NIR)
  – Microwave Radiometer: SAMIR

SAMIR
Dicke Radiometer
3 frequencies
19.35, 22.35 and 31 GHz
150-250 Km GSD
1500 Km swath

TVPayload
Frame imager
341*341 Sq M
1Km GSD
Intensifier coupled
SUPER Vidicon
Refractive optics
## Operational IRS Satellites - Initiation

<table>
<thead>
<tr>
<th>Mission</th>
<th>IRS-1A</th>
<th>IRS-1B</th>
<th>IRS-1C</th>
<th>IRS-1D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>975 kg</td>
<td>975 kg</td>
<td>1250 kg</td>
<td>1250 kg</td>
</tr>
<tr>
<td>Onboard power</td>
<td>600 Watts</td>
<td></td>
<td>809 Watts/(9.6 sqm )</td>
<td></td>
</tr>
<tr>
<td>(Solar Panel, sq m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>S-band, X-band, VHF</td>
<td>S-band, X-band</td>
<td>WiFS (189 m)</td>
<td>LiSS-3 (23.6m)</td>
</tr>
<tr>
<td>Payloads, (Solid State Push Broom Camera)</td>
<td>LiSS-1 (72.5 m)</td>
<td>LiSS-2A, 2B (36.25 m)</td>
<td></td>
<td>WiFS (189 m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LiSS-3 (23.6m)</td>
<td>PAN (&lt;6m)</td>
</tr>
<tr>
<td>Onboard Tape Recorder</td>
<td></td>
<td></td>
<td>62 Gb</td>
<td>62 Gb</td>
</tr>
<tr>
<td>Launch Vehicle/ Site</td>
<td>Vostok/ Baikanur, Kazakhstan</td>
<td>Molniya/ Baikanur, Kazakhstan</td>
<td>PSLV – C1, SHAR</td>
<td></td>
</tr>
<tr>
<td>Orbit # (ht km)</td>
<td>904 km</td>
<td>904 km</td>
<td>817 km</td>
<td>740 x 817 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>99.08°</td>
<td>99.08°</td>
<td>98.69°</td>
<td>98.69</td>
</tr>
<tr>
<td>Repetivity/ (Orbits)</td>
<td>22 days / (307 orbits)</td>
<td>24 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local time &amp;</td>
<td>10.30 a.m.</td>
<td>10.30 a.m.</td>
<td>10.30 a.m</td>
<td>10.30 a.m</td>
</tr>
</tbody>
</table>

# Orbit : Polar Sun Synchronous ; & Local Time : Descending Node
### Resourcesat-1 (IRS-P6)

- **Simultaneous data acquisition at different spatial resolutions for micro to macro level applications**
- **Improved capability in radiometric, spatial and temporal resolutions**

<table>
<thead>
<tr>
<th>Specifications</th>
<th>LISS-4</th>
<th>LISS-3</th>
<th>AWiFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Resolution (m)</td>
<td>5.8 m</td>
<td>23.5 m</td>
<td>56 m</td>
</tr>
<tr>
<td>Swath (km)</td>
<td>23.9 (MX)/ 70 (Mono)</td>
<td>141</td>
<td>370 x 2</td>
</tr>
</tbody>
</table>
| Spectral Bands (μm)     | B2 - 0.52 to 0.59  
B3 - 0.62 to 0.68  
B4 - 0.77 to 0.86  | B2 - 0.52 to 0.59  
B3 - 0.62 to 0.68  
B4 - 0.77 to 0.86  
B5 - 1.55 to 1.70  | B2 - 0.52 to 0.59  
B3 - 0.62 to 0.68  
B4 - 0.77 to 0.86  
B5 - 1.55 to 1.70  |
| Quantization (Bits)     | Best 7 of 10  | 7            | 10          |
| Revisit / Cycle (Days)  | 5 / 24        | 24 / 24      | 5 / 24      |

**Improved capability in radiometric, spatial and temporal resolutions**

**Simultaneous data acquisition at different spatial resolutions for micro to macro level applications**
RSR : Across sensors & missions

Chander et al., 2007, Trans IEEE

Pandya Et al., 2007, J.Ind Soc. Rem Sens, 35, 333
IRS-P3 and P4: Ocean Observations

IRS-P3 (1996)
MOS-A/B/C Spectrometer
- 500m resolution, 200 km Swath
- 18 Bands (0.408-1.6 μm)
WiFS Sensor
- 188m resolution, 810 km swath

IRS-P4 (1999)
OCM Sensor
- 360m resolution, 1420 km Swath
- 8 Bands (0.402-885 μm)
MSMR Sensor
- Microwave passive Radiometer
- 6.6, 10.65, 18, 21 GHz
- 150, 75, 50, 50 km resolution
Oceansat-2: Payloads

Ocean Color Monitor -2

Oceansat-2 is continuity of Oceansat-1 with modification in OCM channels and availability of Scatterometer

Pencil Beam Scanning Scatterometer

Band 765 nm → 740 nm to avoid O₂ absorption

Band 670 nm → 620 nm for better quantification of suspended sediments

- Ku-band 13.515 GHz
- Spatial res., 50 km
- Ocean surface wind speed from 4 m/sec to 24 m/sec
Scatterometer Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>720 Km</td>
</tr>
<tr>
<td>Frequency</td>
<td>13.5156 GHz</td>
</tr>
<tr>
<td>Resolution</td>
<td>50 km X 50 km</td>
</tr>
<tr>
<td>Polarisation</td>
<td>HHI (Inner) and VV (Outer)</td>
</tr>
<tr>
<td>Antenna</td>
<td>Parabola of 1.0 m Dia</td>
</tr>
<tr>
<td>Scanning Rate</td>
<td>20.5 rpm</td>
</tr>
<tr>
<td>Data Rate</td>
<td>13.11 Mbit/sec (Raw)</td>
</tr>
<tr>
<td></td>
<td>74.4 Kbit/Sec (Processed)</td>
</tr>
<tr>
<td>Transmit Power</td>
<td>100 W Peak</td>
</tr>
<tr>
<td>Swath</td>
<td>1400 km</td>
</tr>
<tr>
<td>Wind Speed Range</td>
<td>4 to 24 m/s</td>
</tr>
<tr>
<td>Wind Speed Accuracy</td>
<td>2 m/sec or 10% (Whichever is higher)</td>
</tr>
<tr>
<td>Wind Direction Accuracy</td>
<td>20 deg RMS</td>
</tr>
</tbody>
</table>

Scatterometer Geometry

- **Orbit Track**: 720 Kms
- **Altitude**: 720 Km
- **Frequency**: 13.5156 GHz
- **Resolution**: 50 km X 50 km
- **Polarisation**: HHI (Inner) and VV (Outer)
- **Antenna**: Parabola of 1.0 m Dia
- **Scanning Rate**: 20.5 rpm
- **Data Rate**: 13.11 Mbit/sec (Raw), 74.4 Kbit/Sec (Processed)
- **Transmit Power**: 100 W Peak
- **Swath**: 1400 km
- **Wind Speed Range**: 4 to 24 m/s
- **Wind Speed Accuracy**: 2 m/sec or 10% (Whichever is higher)
- **Wind Direction Accuracy**: 20 deg RMS

**2009 Launch**

- **Scatterometer**: OCEANSAT-2 : SCATTEROMETER
- **Orbit Track**: 720 Kms
- **Altitude**: 720 Km
- **Frequency**: 13.5156 GHz
- **Resolution**: 50 km X 50 km
- **Polarisation**: HHI (Inner) and VV (Outer)
- **Antenna**: Parabola of 1.0 m Dia
- **Scanning Rate**: 20.5 rpm
- **Data Rate**: 13.11 Mbit/sec (Raw), 74.4 Kbit/Sec (Processed)
- **Transmit Power**: 100 W Peak
- **Swath**: 1400 km
- **Wind Speed Range**: 4 to 24 m/s
- **Wind Speed Accuracy**: 2 m/sec or 10% (Whichever is higher)
- **Wind Direction Accuracy**: 20 deg RMS
### CARTOSAT-1 Specifications

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>618 km high, circular Polar Sun Synchronous</td>
</tr>
<tr>
<td>Orbit inclination</td>
<td>98.87 deg</td>
</tr>
<tr>
<td>Orbit period</td>
<td>97 min</td>
</tr>
<tr>
<td>Number of orbits per day</td>
<td>14</td>
</tr>
<tr>
<td>Local time of equator crossing</td>
<td>10.30 AM</td>
</tr>
<tr>
<td>Repetivity</td>
<td>126 days</td>
</tr>
<tr>
<td>Revisit</td>
<td>5 days</td>
</tr>
<tr>
<td>Lift-off mass</td>
<td>1560 kg</td>
</tr>
<tr>
<td>Attitude and orbit control</td>
<td>3-axis body stabilised using Reaction Wheels,</td>
</tr>
<tr>
<td></td>
<td>Magnetic Torquers and Hydrazine Thrusters</td>
</tr>
<tr>
<td>Electrical power</td>
<td>15 sq m Solar Array generating 1100 W,  Two 24 Ah Ni-Cd batteries</td>
</tr>
<tr>
<td>Mission life</td>
<td>5 years</td>
</tr>
</tbody>
</table>

### Payloads

- Two PAN Cameras
  - PAN fore mounted with a tilt of +26 deg
  - PAN aft mounted with a tilt of - 5 deg from the yaw axis to generate stereoscopic imagery

### Instantaneous Geometric Field of View (IGFOV)

- < 2.5 m

- Swath: 30 km
- Spectral Band: 0.50-0.85 Micron
- Data rate: 105 Mbps for each camera
- Solid State Recorder: 120 GB capacity for image data storage
CARTOSAT – 2 / 2A

- Altitude: 630 km / 638 km*
- Inclination: 97.91 deg / 97.94 deg*
- Period: 97.4 minutes
- Local time (D): 9.30 am
- Orbits.day: 14
- Revisit / Repetivity: 4 days / 310 days
- Lift-off mass: 680 kg
- Payload: Panchromatic Camera
- Operational Life: 5 Years

- CARTOSAT 2/2A PAN SENSOR
  - Spectral Range: 0.5 – 0.85
  - Spatial Res.: <1m (81cm nom.)
  - Swath: 9.6 km
  - SSR: 64 GB
  - Data Rate: 336 MBPS
  - On-board Comp.: 3.2:1
  - Transmission: 105 MBPS
CARTOSAT - 2

• High Resolution PAN imaging
  – SWATH (km) : 10
  – SNR : ≥ 180
  – IGFOV (m) : 0.8
  – SWR (%) : ≥ 10

Step and Stare imaging
Indian Mini Series-1/ IMS-1

- **ORBIT**: Polar sun synchronous
- **ALTITUDE**: 635 km
- **MISSION LIFE**: 2 km
- **DIMENSION**: 0.604 x 0.980 x 1.129
- **MASS**: 83 kg
- **POWER**: 2 Sol panel/ 220W
- **DATA STORAGE**: 16 Gb SSR

**HySI Payload**
- **TYPE**: Hypersp. Camera
- **SPECTRAL**: (0.4 – 0.95 µm)
- **NO. BANDS**: 64 fixed bands
- **SPECTRAL Res.**: 8 nanometer
- **SPATIAL Res.**: 505.6 m
- **SWATH**: 129.5 km
- **MASS**: 3.4 kg

**Mx Payload**
- **TYPE**: 4 Band MX CCD Camera
- **SPECTRAL**: B1 (0.45 – 0.52 µm)
- **BANDS**: B2 (0.52 – 0.59 µm)
  - B3 (0.62 – 0.68 µm)
  - B4 (0.77 – 0.86 µm)
- **RESOLUTION**: 37 m
- **SWATH**: 151 km
- **MASS**: 5.9 kg
### RISAT

<table>
<thead>
<tr>
<th><strong>ALTITUDE</strong></th>
<th>586.87 KM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FREQUENCY</strong></td>
<td>5.35 Ghz</td>
</tr>
<tr>
<td><strong>ORBIT</strong></td>
<td>SUN SYNCHRONOUS</td>
</tr>
<tr>
<td><strong>POLARISATION</strong></td>
<td>SINGLE / DUAL/ QUAD POLARISATION</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>RESOLUTION (IN METER)</strong></th>
<th><strong>SINGLE POL</strong></th>
<th><strong>DUAL POL</strong></th>
<th><strong>QUAD POL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HH / HV / VV / VH.</td>
<td>HH+HV / VV+VH</td>
<td>HH+HV+VV+VH</td>
</tr>
<tr>
<td><strong>High Resolution Spotlight</strong></td>
<td>Azimuth 1 m</td>
<td>Azimuth 1 m</td>
<td></td>
</tr>
<tr>
<td><strong>HRS</strong></td>
<td>Sl. Range 0.7 m</td>
<td>Sl. Range 0.7 m</td>
<td></td>
</tr>
<tr>
<td><strong>Fine Resolution Strip map</strong></td>
<td>Azimuth 3 m</td>
<td>Azimuth 3 m</td>
<td>Azimuth 9 m</td>
</tr>
<tr>
<td><strong>FRS</strong></td>
<td>Sl. Range 2 m</td>
<td>Sl. Range 2 m</td>
<td>Sl. Range 4 m</td>
</tr>
<tr>
<td><strong>Medium Resolution SCANSAR</strong></td>
<td>Azimuth 24 m</td>
<td>Azimuth 24 m</td>
<td></td>
</tr>
<tr>
<td><strong>MRS</strong></td>
<td>Sl. Range 8 m</td>
<td>Sl. Range 8 m</td>
<td></td>
</tr>
<tr>
<td><strong>Coarse Resolution SCANSAR</strong></td>
<td>Azimuth 50 m</td>
<td>Azimuth 50 m</td>
<td></td>
</tr>
<tr>
<td><strong>CRS</strong></td>
<td>Sl. Range 8 m</td>
<td>Sl. Range 8 m</td>
<td></td>
</tr>
<tr>
<td><strong>SWATH</strong> (IN km)</td>
<td>10 km x 10 km</td>
<td>SPOT (HRS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 km</td>
<td>STRIP (FRS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 km</td>
<td>STRIP (MRS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>240 km</td>
<td>STRIP (CRS)</td>
<td></td>
</tr>
<tr>
<td><strong>LOOK ANGLE COVERAGE</strong></td>
<td>18.7 degrees to 44.3 degrees</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INCIDENCE ANGLE COVERAGE</strong></td>
<td>20.5 degrees to 49.7 degrees</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SWATH SELECTABILITY</strong></td>
<td>EITHER SIDE OF FLIGHT DIRECTION FROM 200 km TO 600 km FROM THE SUBSATELLITE TRACK</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL NO. OF BEAMS</strong></td>
<td>41</td>
<td></td>
<td>39</td>
</tr>
<tr>
<td><strong>ON BOARD STORAGE</strong></td>
<td>240 Gbits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Imaging SAR : RISAT

Operating Frequency: 5.35 GHz

- High Resolution Spotlight (HRS)
- Fine Resolution Stripmap-1 (FRS-1)
- Fine Resolution Stripmap-2 (FRS-2)
- Medium Resolution Scansar (MRS)
- Coarse Resolution Scansar (CRS)

<table>
<thead>
<tr>
<th>Mode</th>
<th>FRS-1</th>
<th>FRS-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swath (km)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Res. (m)</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Pol.</td>
<td>Single/Dual</td>
<td>Quad</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode</th>
<th>HRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swath (km x km)</td>
<td>10 x 10</td>
</tr>
<tr>
<td>Res. (m)</td>
<td>1</td>
</tr>
<tr>
<td>Pol.</td>
<td>Single/Dual</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode</th>
<th>MRS</th>
<th>CRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swath (km)</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>Res. (m)</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Pol.</td>
<td>Single/Dual</td>
<td>Single/Dual</td>
</tr>
</tbody>
</table>
Geostationary Operational Met. Satellites

- INSAT – 1 Series 1982-90 (1A/ 1B/ 1C/ 1D); INSAT – 2 Series 1991-95 (2A/ 2B/ 2C/ 2D); **VHRR**
  - Visible 2.75 km
  - IR 11 km

- INSAT – 2E; INSAT – 3A; VHRR + CCD
  - VHRR: Visible 2 km, IR 8 km
  - CCD: Multispectral 3band, 1 km

- KALPANA (Met only payload), 2002, VHRR
Megha-Tropiques - A Joint ISRO-CNES Mission

For studying water cycle and energy exchanges in tropical regions

Launch: 12 Oct 2011

Low inclination (20º) for frequent simultaneous observations of tropics
- Water vapour, Clouds
- Cloud condensed water,
- Precipitation, Evaporation

Contribution to Global Precipitation Mission (GPM)

<table>
<thead>
<tr>
<th>Payload</th>
<th>Type</th>
<th>Characteristic</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADRAS</td>
<td>Microwave imager</td>
<td>Five Frequency, 9-channel Microwave imager 18, 23, 36, 89 and 157 Ghz All in V and H Polarisations except for 23 GHz (V only)</td>
<td>Surface wind speed, total water vapour, cloud liquid water, rainfall, cloud ice</td>
</tr>
<tr>
<td>SAPHIR</td>
<td>Sounder</td>
<td>Six-channel millimetre wave Humidity sounder at 183 Ghz (Water vapour Resonance Frequency)</td>
<td>Vertical humidity profiling at 6 altitudes with good horizontal resolution</td>
</tr>
<tr>
<td>SCARAB</td>
<td>Scanner</td>
<td>Four-channel Earth radiation budget instrument 0.5-0.7 μm, 0.2-4 μm, 10.5-12.5 μm, 0.2-200 μm, with a spatial resolution of 40 km</td>
<td>Long-wave radiation fluxes</td>
</tr>
<tr>
<td>ROSA</td>
<td>Sounder</td>
<td>Radio Occultation System to obtain vertical profiles of humidity, temperature, Aerosol contents, etc., GPS receivers at L1 and L2 channels</td>
<td>Vertical profiles of humidity, temperature, and aerosol contents with good vertical resolution</td>
</tr>
</tbody>
</table>
Initial Megha-Tropiques data products

SAPHIR Relative Humidity – Two Layers

MADRAS BT Data

SAPHIR CHANNEL 4, ORB.15_16, DOP_13Oct2011, BRIGHTNESS, TEMPERATURE, DEG.K

MADRAS GP Data

MT-MADRAS Water Vapour (g/cm**2) – Oct. 14-15 2011
FUTURE EO SATELLITES & SENSORS

SARAL (2013)
INSAT 3D (2013)

Resourcesat – 2A, GISAT, Oceansat – 3,
RISAT – 1A, Cartosat – 2C
EO – Near Future Satellites

**SARAL**
Satellite with ARgos and ALtika - Joint ISRO-CNES Mission

**Payloads**
- Ka-band Altimeter (~35.5GHz)
- Dual freq Radiometer (23.8/36.8 GHz)

**Status**
- Launch by PSLV in early 2013

**GISAT**
Multiple acquisition capability from a Geosynchronous Orbit

**Payloads**
- High resolution multi-spectral VNIR (HRMX-VNIR): 50m Res.
- Hyper spectral VNIR & SWIR: 320m and 192m Res.
- High resolution Multi-spectral (HRMX-TIR): 1.5km Res.

**Status**
- Launch by PSLV during 2016-17

**INSAT - 3D**
For improved understanding of weather systems

**Payloads**
- 19 channel Sounder
- 6 Channel Imager

**Status**
- Launch by 2013

**Resourcesat-2A**
Land and Water Resources Applications – Continuity Mission

**Payloads**
- LISS IV Mx, LISS III and AWiFS

**Status**
- Launch by PSLV during 2015-16

Followed by satellites with high resolution cameras, hyperspectral sensors, Oceansat-3,...
ISRO contribution: CEOS Virtual Constellations

- Land Surface Imaging (LSI) – Resourcesat-2
- Ocean Colour Radiometry (OCR) – Oceansat-2 OCM
- Ocean Surface Vector Wind (OSVW) - Oceansat-2 Scatterometer
- Precipitation (PC) – Megha-Tropiques
- Ocean Surface Topography (OST) – SARAL
- Sea Surface Temperature (SST-VC) - (under discussion)
- Atmospheric Composition (ACC)
Thank You

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http://www.nrsc.gov.in
SARAL : Satellite for ARGOS & ALTIFA
INSAT 3D

**Sounder**

19 channel Sounder

**Imager**

Advanced 6-channel imager

Sounder: 19 channels with spatial resolution of 10 km
Imager: 6 channel with spatial resolution of 1 km to 8 km

Applications: Improved estimation of water vapour content, cloud, wind vector, upper tropospheric humidity, sea surface temperature and surface insolation

INSAT-3D Weighting Function over Indian Region (July)
## INSAT 3D: IMAGER: 6 Band

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Spectrum (mm)</th>
<th>IGFOV (km)</th>
<th>S/N/ Or NEDT (K)</th>
<th>Scene Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.55-0.75</td>
<td>1</td>
<td>150:1</td>
<td>100% albedo</td>
</tr>
<tr>
<td>2</td>
<td>1.55-1.70</td>
<td>1</td>
<td>150:1</td>
<td>100% albedo</td>
</tr>
<tr>
<td>3</td>
<td>3.80-4.00</td>
<td>4</td>
<td>1.40 K</td>
<td>300 K</td>
</tr>
<tr>
<td>4</td>
<td>6.50-7.00</td>
<td>8</td>
<td>1.00 K</td>
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<tr>
<td>5</td>
<td>10.2-11.3</td>
<td>4</td>
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<td>300 K</td>
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<td>6</td>
<td>11.5-12.5</td>
<td>4</td>
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<td>300 K</td>
</tr>
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