TRISHNA Project, Scientific Objectives and Specifications

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And TRISHNA mission Principal Investigators:
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OUTLINE

- Global context
- Presentation of the program and cooperation ISRO/CNES
- TRISHNA scientific objectives
- Main mission specifications and justification
- TRISHNA products
- TRISHNA science groups
Global context

Global change (climate, population growth, land use, urbanization, deforestation…) ⇒ increasing scarcity and deteriorating quality of the water resource

Monitoring of the water cycle is becoming more and more crucial


Physical water scarcity  Economic water scarcity  Little or no water scarcity
Global context

**Land and sea surface temp.** (LST and SST) are key signatures of water and energy budgets
- evaluate the current drifts and assess their impacts on surface
- calibrate and validate the models predicting the evolution of ecosystems → adapting the mitigation methodologies for a sustainable development

Measurements in the Thermal Infrared (TIR) domain → LST, SST

**Spatio-temporal variability of the surface:**
- Complexity of physical and biological processes → access to local scale needed for decision and management policies
- Short-time scale variability (meteo forcing, human activities…)

Need for Spatial systems in the TIR with:
- high spatial resolution
- high revisit capacities

**SUCH A SYSTEM DOES NOT EXIST TODAY**
Need for a high spatio temporal resolution TIR mission

Current satellite TIR data: a resolution/revisit dilemma

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Geostationary satellites (MSG/SEVIRI, GOES, INSAT, GMS...)</th>
<th>Polar meteo satellites 1km (MODIS, SUOMI NPP VIRSS...)</th>
<th>EO satellites (TIR on LANDSAT, ASTER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisit</td>
<td>Daily AET → Nov 10, 2017 EUMETSAT</td>
<td>ET (mm/day), July 8, 2008, Crau region (S-E France)</td>
<td>ET (mm/day), July 8, 2008, Crau region (S-E France)</td>
</tr>
<tr>
<td></td>
<td>Resolution &gt; 3 km</td>
<td>1 km</td>
<td>60 - 120m</td>
</tr>
<tr>
<td></td>
<td>15 min</td>
<td>1 day</td>
<td>18 days</td>
</tr>
</tbody>
</table>

**Program background history**

- **MISTIGRI (2008/2011) CNES**
  - Mission Design Review
  - Preliminary Requirements Review

- **THIRSTY (2013/2014) CNES / JPL**
  - Mission Design Review
  - JPL decision to fly onboard ISS

- **SOIF (2015) CNES**
  - Mission Design Review
  - Cooperation to be found for program decision

- **TRISHNA (2016/2019) CNES/ISRO**
  - Mission Design Review
  - Preliminary Requirements Review October 2019

But we mean: good for you, of course 😊

With the long-term and constant involvement of Jean Pierre Lagouarde (INRA) → Jean Louis Roujean (CESBIO)
Cooperation Agreement between CNES and ISRO for a reinforced cooperation in space activities - signed in April 2015
To set up the terms and conditions of a favorable cooperative framework for the implementation of any future joint mission

Implementing Arrangement for Trishna - signed January 24, 2016
To conduct definition studies for a potential joint thermal-infrared (TIR) Earth Observation mission

**Phase 1**
- Finalisation of the mission requirements and associated data policy principles
- Definition of work share and responsibilities
→ *Closed in November 2017 (Mission Definition Review)*

**Phase 2**
- Finalization of the system requirements
- Definition of the satellite configuration, the payload concept, the launch strategy
- Development plan and costs definition
- Preparation of the Arrangement for realization Phase
→ *Closed in October 2019 (Preliminary Requirement Review)*
TRISHNA system architecture and workshare between ISRO and CNES
<table>
<thead>
<tr>
<th><strong>Mass</strong></th>
<th>195 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td>265 W</td>
</tr>
<tr>
<td><strong>Optics</strong></td>
<td>Three-mirror anastigmat telescope</td>
</tr>
<tr>
<td><strong>Number of spectral bands</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Band names</strong></td>
<td>TIR1 – TIR2 – TIR3 – TIR4</td>
</tr>
<tr>
<td><strong>Specified central wavelengths</strong></td>
<td>8.65µm – 9.0µm – 10.6µm – 11.6µm</td>
</tr>
<tr>
<td><strong>Specified FWHM per band</strong></td>
<td>0.35µm – 0.35µm – 0.7µm – 1.0µm</td>
</tr>
<tr>
<td><strong>Radiometric accuracy</strong></td>
<td>0.5K at 300K</td>
</tr>
<tr>
<td><strong>Radiometric precision</strong></td>
<td>0.2K at 300K</td>
</tr>
<tr>
<td><strong>Dynamic range</strong></td>
<td>250K – 400K</td>
</tr>
<tr>
<td><strong>Aperture size</strong></td>
<td>150mm</td>
</tr>
<tr>
<td><strong>Focal length</strong></td>
<td>400mm</td>
</tr>
<tr>
<td><strong>Focal plane temperature</strong></td>
<td>60K</td>
</tr>
<tr>
<td><strong>On-board calibration</strong></td>
<td>1 blackbody + 1 cold space view</td>
</tr>
<tr>
<td><strong>Scan cycle</strong></td>
<td>5 sec</td>
</tr>
</tbody>
</table>
TRISHNA Scientific objectives

1) **Ecosystem stress and water use** design driver
2) **Coastal and inland waters** design driver
3) **Urban ecosystems monitoring**
4) **Solid Earth**
5) **Cryosphere**
6) **Atmosphere**
**TRISHNA Scientific objectives: design drivers**

From *TRISHNA User Requirement Document*

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### Ecosystem stress and water use

**Agriculture/forestry**
- water stress detection / water needs / irrigation optimisation
- water resources management
- growth/ crop production, food security
- impact of agricultural practices on water use, climate change adaptation
- forest fire risks, frost detection…

**Biogeochemical cycles**
- carbon cycle ↔ global warming processes
- water quality
- soil pollution
- arctic permafrost

**Hydrology**
- link with meteorology (mesoscale circulation)
- water budgets and biogeochemistry at watershed scale

**Ecosystem monitoring, ecology**
- microclimates, biodiversity
- natural vegetation droughts

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### Coastal and inland waters

**Coastal waters**
- Submesoscale activity (mixing processes) ↔ ecosystems productivity (phytoplankton)
- Gaz fluxes (CO$_2$, CH$_4$) at the air-sea interfaces
- Coastal zone monitoring and management: water quality, algae blooms, halieutic resource, fresh water resurgences, discharges (water, pollutants, thermal plumes…)

**Inland waters (lakes and rivers)**
- GTN-L lakes (GCOS) [Essential Climate Variable Ts]
- Deltas, estuary hydrology, lagunaes
- Biological activity and productivity
- Warning of water borne diseases (application to human health)
- Thermal discharges

**Sea ice (at local scale)**
- Monitoring melting/freezing processes (meltponds, leads, polynyas)
- Feedbacks climate ↔ melting ice
**Urban microclimates**

- Urban heat island and comfort (*welfare, health...*)
- Urban vegetation
- Urban and peri-urban hydrology (*run-off, urban planning*)
- Urban meteorology and atm. flow (*dispersion of pollutants...*)
- Anthropogenic fluxes and energy consumptions (*heating, air conditionning...*)

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>3.3</td>
</tr>
<tr>
<td>2050</td>
<td>~5</td>
</tr>
</tbody>
</table>

*Urban population (10⁹ inhabitants)*

**Solid Earth**

- Monitoring volcanic activity (*prediction of eruptions, mitigation of risks...*)
- Detection of peat and coal fires (*pollution, CO₂...*)
- Detection of thermal anomalies (*geothermal exploration, earthquakes precursors...*)

**Cryosphere**

- Melt runoff using Degree-Day and Energy Balance approach
- Identification of debris cover/thickness over glacier ice
- Snow metamorphism processes and its effect on snow reflectance
- Lake dynamics at High alt. and Basin/Sub-basin scale dynamics
- Retrieval of sea ice surface temperature in polar region

**Atmosphere**

- surface radiation budget
- clouds (*high clouds, cirrus...*)
- atmospheric water vapor

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**From TRISHNA User Requirement Document**
Mission specifications: revisit = 3 days, nadir resolution = 57m

**Revisit** guided by:
- Cloud frequency / data availability
- Technical constraints: swath, arrays detector size, view zenith angle
- Expected products (AET) accuracy

1 day is the goal
3 days is the best possible with single satellite

**Spatial resolution** guided by:
- Field size
- Technical constraints: arrays detector size, swath
- LST accuracy (vs atmospheric turbulence induced fluctuations)

50 - 60 m (nadir)
< 100m (edge)
Overpass time must cope with max sensitivity for flux estimation

Noon to 1PM LST → max accuracy on fluxes retrieval

Minimizing the sensitivity of LST measurement to overpass time

→ 1PM LST more suited to models with 30mn-1h time steps
→ 1PM LST minimizes impact of time differences (orbit)

SST measurements

1PM LST → 1AM nighttime overpass preferred for water surfaces temperature (no skin thermal effects)

Hot spot impact

For mid-latitudes, scan perpendicular to 1PM principal plane → mitigation of hot spot effects

⚠ Not true for inter-tropical areas!
Mission specifications: NeDT = 0.2K @300K, ARA = 0.5K @300K

LST measurements are affected by atmospheric turbulence:

- Temporal fluctuations over dry maize field or bare soil (from experimental measurements)
- SBL turbulence effect on LST is smoothed by spatial integration on the pixel
- PBL turbulence affects LST whatever the pixel size → uncertainty on instantaneous LST meas. from space

Specifications:
- Specified NeDT at instrument level: 0.2K
- Absolute Radiometric Accuracy: 0.5K

Impact on level 2 products: Atmospheric correction / Temperature-emissivity separation (TES): 1K to 1.5K uncertainty on LST

LST systematic uncertainty of 1.5 K is sufficient for acquiring a daily ET accuracy of 5%

Allen et al., 2007
Sobrino et al. 2016

Experimental characterization of the uncertainty on LST, at 50m resolution:

- +/-0.6K for ~60% of the measurements
- +/-0.8K for ~80% of the measurements

Lagouarde et al., RSE 2013
Lagouarde et al., RSE 2015
Complementarity
TIR/VNIR/SWIR

- TIR \(\rightarrow\) water stress
- VNIR \(\rightarrow\) vegetation status
- VNIR provides information on potential “accidents” in the temporal evolution of the vegetation status
- SWIR bands for thin cirrus cloud detection (1.38μm) and snow/cloud discrimination (1.6μm)

‘Ecosystem stress’ (vegetation) scientific objective
- Rapid surface changes: phenology (growth, flowering, senescence…), water stress, harvesting…
- Albedo needed for energy budget and \textit{in fine} AET (actual evapotranspiration)
- Model constraining

‘Coastal and inland waters’ scientific objective
- Information on biological activity needed (chlorophylle concentration…)
- Dependence with turbulence and mixing processes (rapidly changing)

‘Urban ecosystem monitoring’ scientific objective
- Complexity of the structure \(\rightarrow\) lots of shadows \(\rightarrow\) less correlation between TIR and VNIR measurements if not acquired at the same time
Mission specifications: orbit selection

**Directional anisotropy in TIR: still a research field**
- A uniform viewing configuration on a given site allows minimizing its impact
- With a constant viewing configuration, the angular effect appears as a bias, and not as an error (crucial for temporal analysis)

**Hot-spot**
- On a 3-day orbit, intertropical zones measurements can be inside hot-spot conditions, affecting seasonal-long time series
- Different viewing configurations guarantee hot-spot free acquisitions, and provides valuable data for studying directional anisotropy

**Selected orbit: 761 km altitude / 8 days revisit**
- Repeatable geometric conditions every 8 days
- Compatible with **global coverage every 3 days** with extended swath (+/- 33 deg swath angle)
- Provides 2 hot-spot free acquisitions every 8 days on inter-tropical regions at any period of the year
- Drawback: swath is extended

*Number of accesses in 8 days (with scan ±34 deg) →*
## Mission specifications: spectral bands

<table>
<thead>
<tr>
<th>Band name</th>
<th>Wavelength Center (nm)</th>
<th>FWHM (nm)</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>485</td>
<td>70</td>
<td>Detection of low clouds</td>
</tr>
<tr>
<td>Green</td>
<td>555</td>
<td>70</td>
<td>Coastal, sediments, snow</td>
</tr>
<tr>
<td>Red</td>
<td>670</td>
<td>60</td>
<td>Vegetation (LAI, fCOVER, NDVI, ...)</td>
</tr>
<tr>
<td>NIR</td>
<td>860</td>
<td>40</td>
<td>Vegetation (LAI, fCOVER, NDVI, ...)</td>
</tr>
<tr>
<td>Cirrus</td>
<td>1380</td>
<td>30</td>
<td>Detection of thin cirrus clouds</td>
</tr>
<tr>
<td>SWIR</td>
<td>1610</td>
<td>100</td>
<td>AOD, snow/cloud discrimination, vgt stress, burnt areas</td>
</tr>
</tbody>
</table>

+ 910nm band for water vapor content estimation (under study)

<table>
<thead>
<tr>
<th>Band name</th>
<th>Wavelength Center (µm)</th>
<th>FWHM (µm)</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIR 1</td>
<td>8.65</td>
<td>0.35</td>
<td>Temperature/emissivity separation</td>
</tr>
<tr>
<td>TIR 2</td>
<td>9.0</td>
<td>0.35</td>
<td>Temperature/emissivity separation</td>
</tr>
<tr>
<td>TIR 3</td>
<td>10.6</td>
<td>0.7</td>
<td>Split-window</td>
</tr>
<tr>
<td>TIR 4</td>
<td>11.6</td>
<td>1.0</td>
<td>Split-window</td>
</tr>
</tbody>
</table>

Source: TRISHNA SMRD V3.0
# Mission specifications: spectral bands

<table>
<thead>
<tr>
<th>Band name</th>
<th>Wavelength Center (nm)</th>
<th>FWHM (nm)</th>
<th>( L_{\text{typ}} ) (W/m(^2)/sr/µm)</th>
<th>( L_{\text{max}} ) (W/m(^2)/sr/µm)</th>
<th>Required SNR @ ( L_{\text{typ}} ) (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>485</td>
<td>70</td>
<td>30</td>
<td>663.5</td>
<td>50</td>
</tr>
<tr>
<td>Green</td>
<td>555</td>
<td>70</td>
<td>30</td>
<td>600.5</td>
<td>100</td>
</tr>
<tr>
<td>Red</td>
<td>670</td>
<td>60</td>
<td>20</td>
<td>486.1</td>
<td>100</td>
</tr>
<tr>
<td>NIR</td>
<td>860</td>
<td>40</td>
<td>30</td>
<td>325.3</td>
<td>100</td>
</tr>
<tr>
<td>Cirrus</td>
<td>1380</td>
<td>30</td>
<td>6</td>
<td>55.0</td>
<td>25</td>
</tr>
<tr>
<td>SWIR</td>
<td>1610</td>
<td>100</td>
<td>4</td>
<td>77.9</td>
<td>100</td>
</tr>
</tbody>
</table>

(*) expressed at native GSD (57m)

<table>
<thead>
<tr>
<th>Band name</th>
<th>Wavelength Center (µm)</th>
<th>FWHM (µm)</th>
<th>NeDT(_{\text{threshold}}) @300K (K)</th>
<th>NeDT(_{\text{goal}}) @300K (K)</th>
<th>T(_{\text{saturation}}) (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIR 1</td>
<td>8.65</td>
<td>0.35</td>
<td>0.3</td>
<td>0.25</td>
<td>400</td>
</tr>
<tr>
<td>TIR 2</td>
<td>9.0</td>
<td>0.35</td>
<td>0.3</td>
<td>0.25</td>
<td>400</td>
</tr>
<tr>
<td>TIR 3</td>
<td>10.6</td>
<td>0.7</td>
<td>0.25</td>
<td>0.2</td>
<td>400</td>
</tr>
<tr>
<td>TIR 4</td>
<td>11.6</td>
<td>1.0</td>
<td>0.25</td>
<td>0.2</td>
<td>400</td>
</tr>
</tbody>
</table>

*Source: TRISHNA SMRD V3.0*
TRISHNA products (under definition)

<table>
<thead>
<tr>
<th>Product level</th>
<th>VNIR &amp; SWIR</th>
<th>TIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Raw observation data</td>
<td>Raw observation data</td>
</tr>
</tbody>
</table>
| 1             | Ortho-rectified image  
Coarse cloud mask  
Top-of-atm. reflectance | Ortho-rectified image  
Coarse cloud mask  
Top-of-atm. Radiance  
Brightness temperature |
| 2a            | Radiative variables:  
- Scene classification (Cloud, Shadows, Water, Snow, Land)  
- Surface reflectance after atm. correction  
- Atmospheric variables (water vapour, AOT)  
Albedo | Radiative variables:  
- Scene classification (Cloud, Shadows, Water, Snow)  
- Surface radiance after atm. Correction  
- Surface temperature  
- Surface emissivity |
| 2b            | Biophysical variables (*ecosystem stress and water use*):  
- leaf area index, fractional vegetation cover, fAPAR ...  
- net radiation, evapo-transpiration, water stress index ... | |
| 3a            | Periodic Syntheses (decadal, monthly) of radiative variables (see Level 2A) | |
| 3b            | Periodic Syntheses (decadal, monthly) of biophysical variables (see Level 2B)  
+  
- land cover  
- mask of irrigated crops | |
TRISHNA science groups

Mission sub-groups:
- Ecosystem stress and water use
- Coastal and inland waters
- Urban microclimate monitoring
- Solid Earth
- Cryosphere
- Atmosphere
- CAL/VAL
- Definition of the products

Organization:
- French / Indian mirror organization involving local research entities
- Objectives: definition of the expected variables and associated precision, products, algorithms, cal/val strategy
  - joint Indo-french ATBDs
- Synergies to develop with ECOSTRESS, SBG, LSTM science teams

Next milestones:
- TRISHNA session at RAQRS 2020 (*ipl.uv.es/raqrs*)
- TRISHNA science workshop in Bangalore (Nov 2020)
- TRISHNA symposium in Toulouse (End 2021 / Beg 2022)
TRISHNA Mission at a glance

- ISRO/CNES cooperation, launch in 2025
- Focus on ecosystem stress and water use
- Global coverage
- 4 TIR bands + 4 VNIR bands + 2 SWIR bands
- Revisit: 3 acquisitions per 8 days period
  761 km-8 day orbit reducing hot spot constraints in intertropical zone
- $\pm 34^\circ$ scan angle, 1030 km swath
- Nadir spatial resolution (VNIR-SWIR-TIR):
  57 m for continental and coastal areas, binned at 1 km over open ocean
- Overpass time: 1 PM $\pm$ 15 mn
- NeDT 0.2K
- Indo-French(*) science mission group, synergies to develop with ECOSTRESS, SBG, LSTM science & application teams (*) with European contributors
TRISHNA science contacts

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