S4PRO

SMART AND SCALABLE SATELLITE HIGH SPEED PROCESSING CHAIN

Most common application areas that can benefit from a new generation processing chain

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MAIN CHALLENGES

The **main ambition** related to the optical case is to:

select and define a use case or **application**

for which its **algorithms** can be developed and **optimized to run** on

a **power efficient** and **high performance space processing chain** for LEO missions

HIGH-SPEED DATA CHAIN

COMPLEX ALGORITHM

EMBEDDED SOFTWARE LIBRARY

OPTIMISED HARDWARE & SOFTWARE

Ship detection

Vegetation monitoring

Optical Applications

Application	Scenario	Resolution	Area of interest	Swath	Spectrum	Revisit Time	Latency Time	Type	Suitability for onboard	Usefulness of onboard application
Agriculture	Precision Farming	0.5-3 m	Europe, US	50 km	VIS+NIR / Hyperspectral	2/3 days	1 day	Support t Operatior		
	Crop Health mapping	5-10 m	Global	50 km	Hyperspectral	Weekly	1 da	Routine/N		
	Crop pests	5-10 m	Global	50 km	Hyperspectral	Weekly	1 day	Routine/N		
	Crop yeld prediction	5-10 m	Global				2-3 days	Routine/N		
	Illicit crop monitoring	1-5 m	Asia, South Am				2-3 days	Support t		
Forestry	Forest stock mapping	30-100 m	North-Europea Countries				15 days	Routine/N		
	Burn scar mapping	1-50 m	Europe, US				2-3 days	Support t		
	Illegal deforestation	10-100 m	Central-South				1 day	Support t		
Land monitoring	Urba		al				15 days	Routine/N		
	Air p		al				1 day	Urgent ta		
	Soil s		pe			y	2-3 days	Routine/N		
	Land		al				15 days	Routine/N		
Maritime monitoring	Oil sp		al				<6 hours	Urgent ta		
	Hydr		al				1 day	Routine/N		
	Ship		al				<6 hours	Urgent ta		
	Illega		al				<6 hours	Routine/N		
	Sea r		al				15 days	Routine/N		
	Ship		al				<6 hours	Urgent ta		
Disaster monitoring	Flood		Europe				<6 hours	Urgent ta		
	Fores		pe, US	>100 km	VIS+NIR	Daily	<6 hours	Urgent ta		
	Hurri		Caribbean, SE Asia	> 100 km	VIS	Daily	1 day	Urgent ta		
	Earth		al	100 km	VIS	Daily	<6 hours	Urgent ta		
	Drou		al	100 km	VIS+NIR / Hyperspectral	Daily	1 day	Monitorir		
	Illega		al	100 km	Hyperspectral	Daily	1 day	Urgent ta		
Security	Hom		US for the reign territory but off-shore/risky s	50 km	PAN	Daily	<6 hours	Urgent ta		
Natural resource management	Wate		al	>100 km	VIS	2/3 days	1 day	Routine/N		
	Oil ar		al	>100 km	VIS	Weekly/Monthly	2-3 days	Support t		

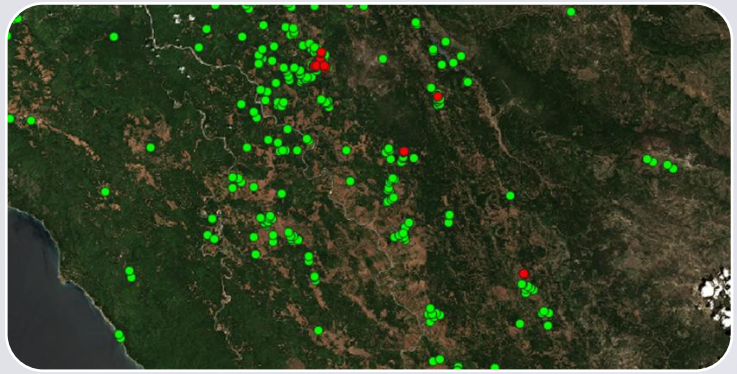
- Agriculture
- Forestry
- Land monitoring
- Maritime monitoring
- Disaster monitoring
- Security
- Natural resource management

For example:

- *Precision Farming*
- *Crop Health mapping*
- *Crop pests*
- *Crop yield prediction*
- *Illicit crop monitoring*

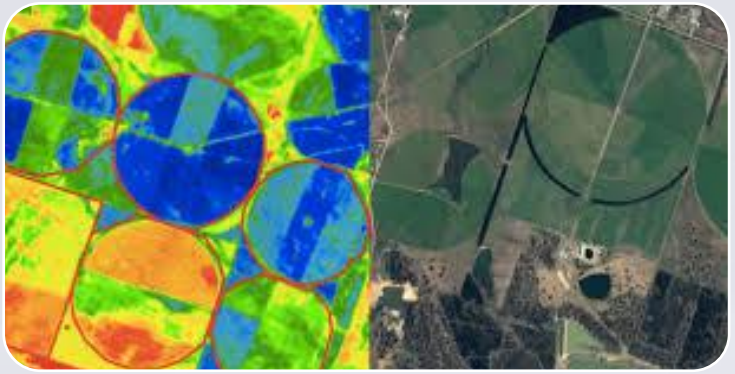
- Application
- Scenario
- Resolution
- Area of interest
- Swath
- Spectrum
- Revisit Time
- Latency Time
- Type
- Suitability for onboard development
- Usefulness of onboard application

Applications - Agriculture



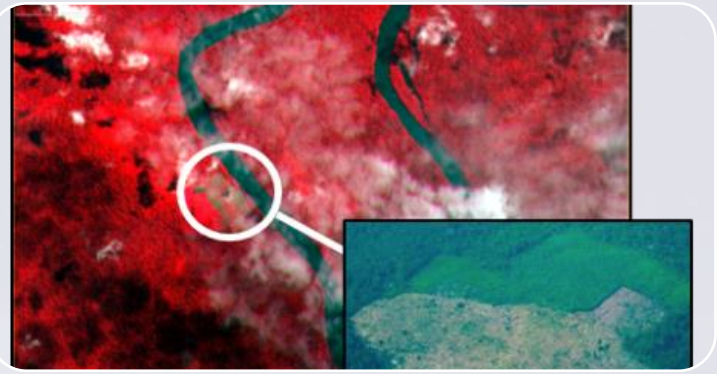
Crop Health Mapping

- Normalized Differential Vegetation Index (NDVI) proportional to the amount of chlorophyll.
- Pinpointing areas of concern and apply countermeasures (fertilizer, water)
- Normalized ratio of the Red and NIR bands



Crop Pests

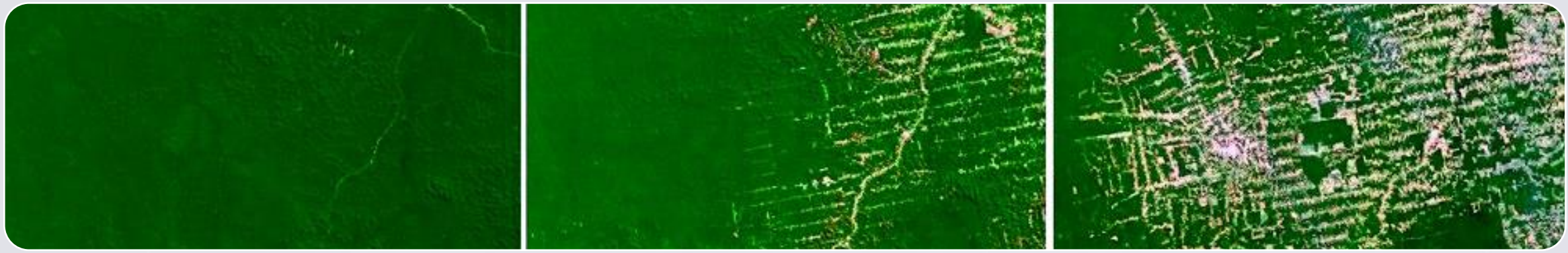
- Spatial distribution information of diseases and pests over a large area with relatively low cost.
- Changes in pigment, chemical concentrations, cell structure, nutrient, water uptake, and gas exchange of the canopy can cause differences in color, temperature and reflectance characteristics.



Illicit Crop Monitoring

- Imagery acquisition is programmed to coincide with forecast harvest and crop cycle events to reveal areas of cultivation.
- Satellite imagery enables accurate information to be determined concerning crop yield and annual change

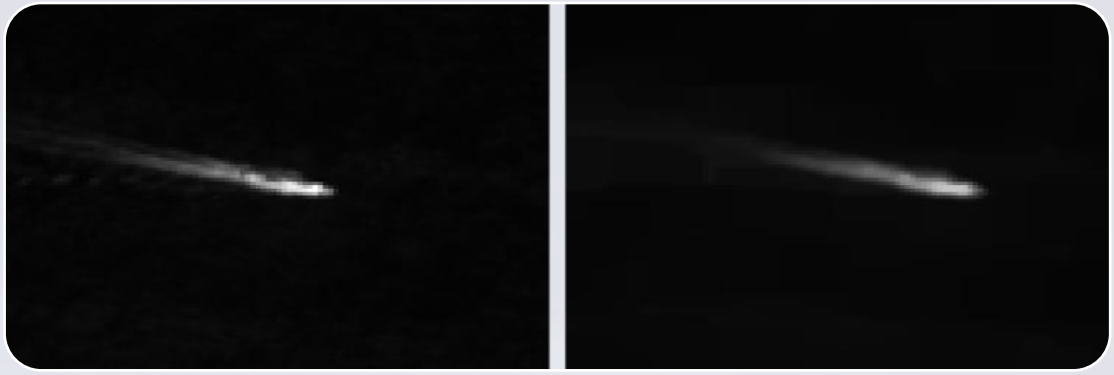
Applications - Forestry



Illegal Deforestation

- Notifying users in real time of new bald patches in the world's forests.
- Algorithms that compare each pixel in the new image to the previous years of images. If a significant difference in the pixel's patterns is sensed, an alert is triggered.
- Currently this is done for example by MODIS on NASA's Terra satellite (250m per pixel). This is too big to spot small changes in land cover, so it can take computer programs that process MODIS data weeks or even months to detect that a forest is being cleared.
- Therefore, pixels with smaller ground dimension can provide great advantage.

Applications – Maritime Monitoring



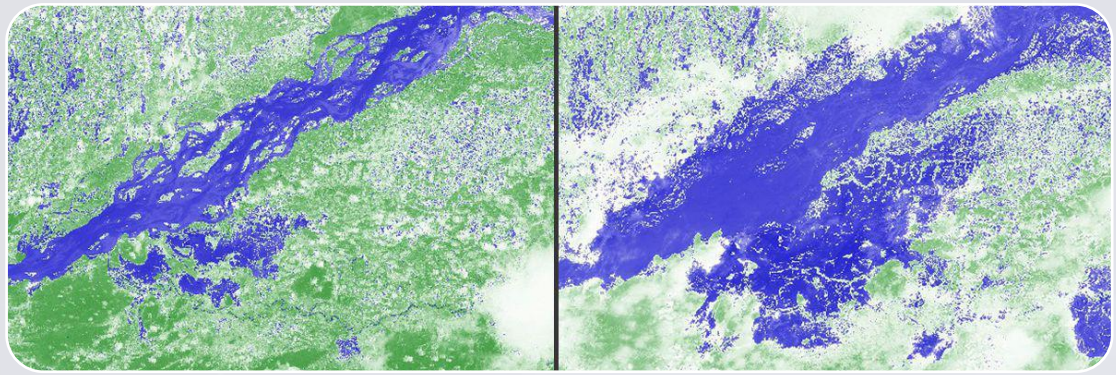
Oil Spill Monitoring

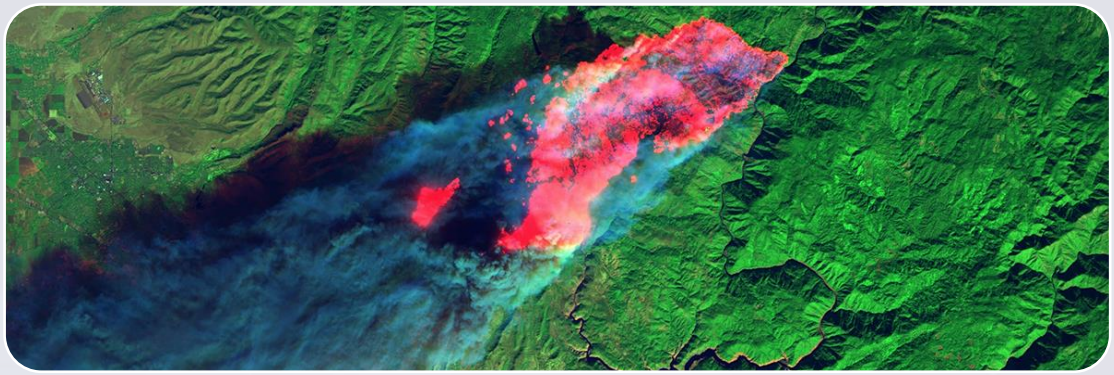
- Immediate threat to the ecosystem.
- High temporal resolution, due to the changing nature of the oil.
- High spatial resolution, to identify individual small oil patches (windrows).
- Wide spectral resolution, for distinguishing the oil from the adjacent water.

Ship Detection and Identification

- Ability to localize any vessel of interest.
- Can be coupled with various types of information provided by the user (expected location or last known position, search & rescue system, tracking systems, etc.).
- It is possible to estimate characteristics, such as length, speed, heading, and load

Applications – Disaster Monitoring





Flooding

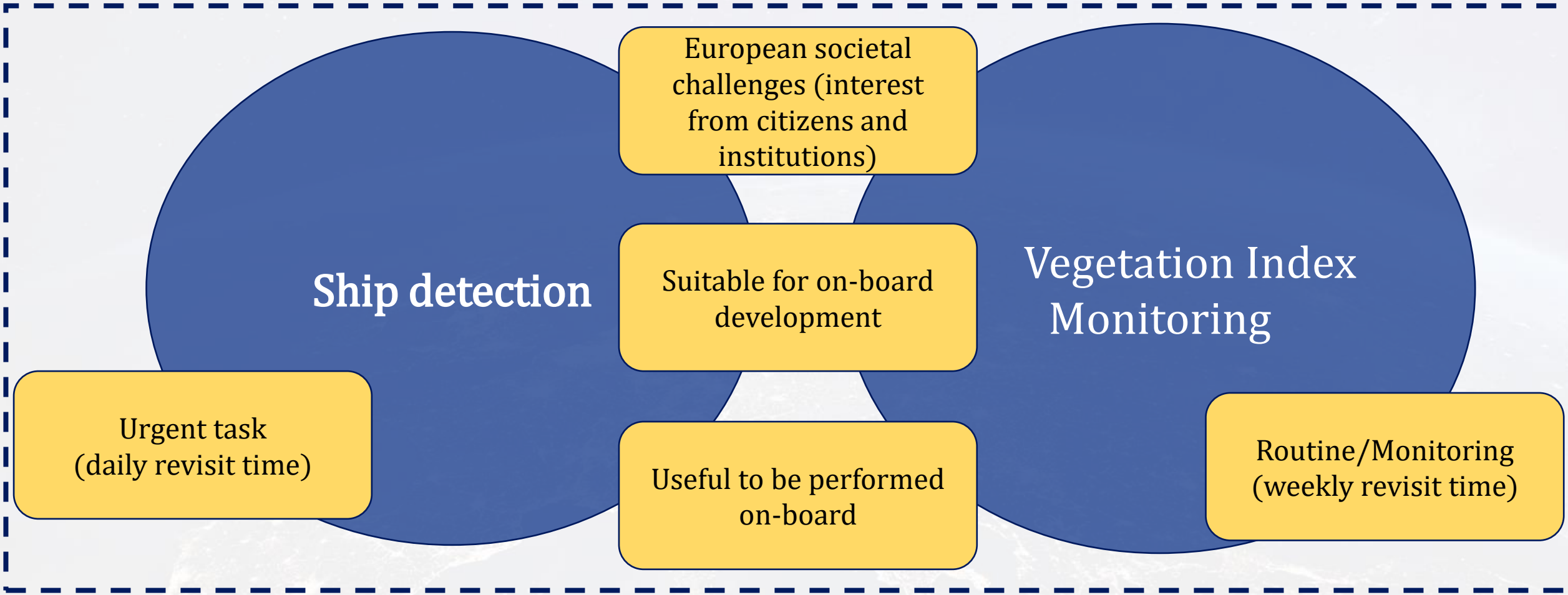
- In developing countries, locating flood waters in order to assess the risk and help decision-makers prioritize aid efforts is vital.
- Satellite-based tools can help evaluate ground conditions, monitoring soil moisture, water levels and changes to these over time.
- Medium/high resolution optical imagery and ground truth measurements to identify changes in levels.

Forest Fires

- Red and IR bands (NIR, TIR) to detect fires.
- Drastic difference in reflectance and signal intensity in the pixel can immediately trigger the detection.
- Quick alerts can help focusing the attention of ground surveillance on the correct spot, to early contain and stop a fire.

CASE STUDY

Good envelop of user applications



CASE STUDY

- **USER NEEDS and HIGH-LEVEL Requirements for the S4PRO SYSTEM:**

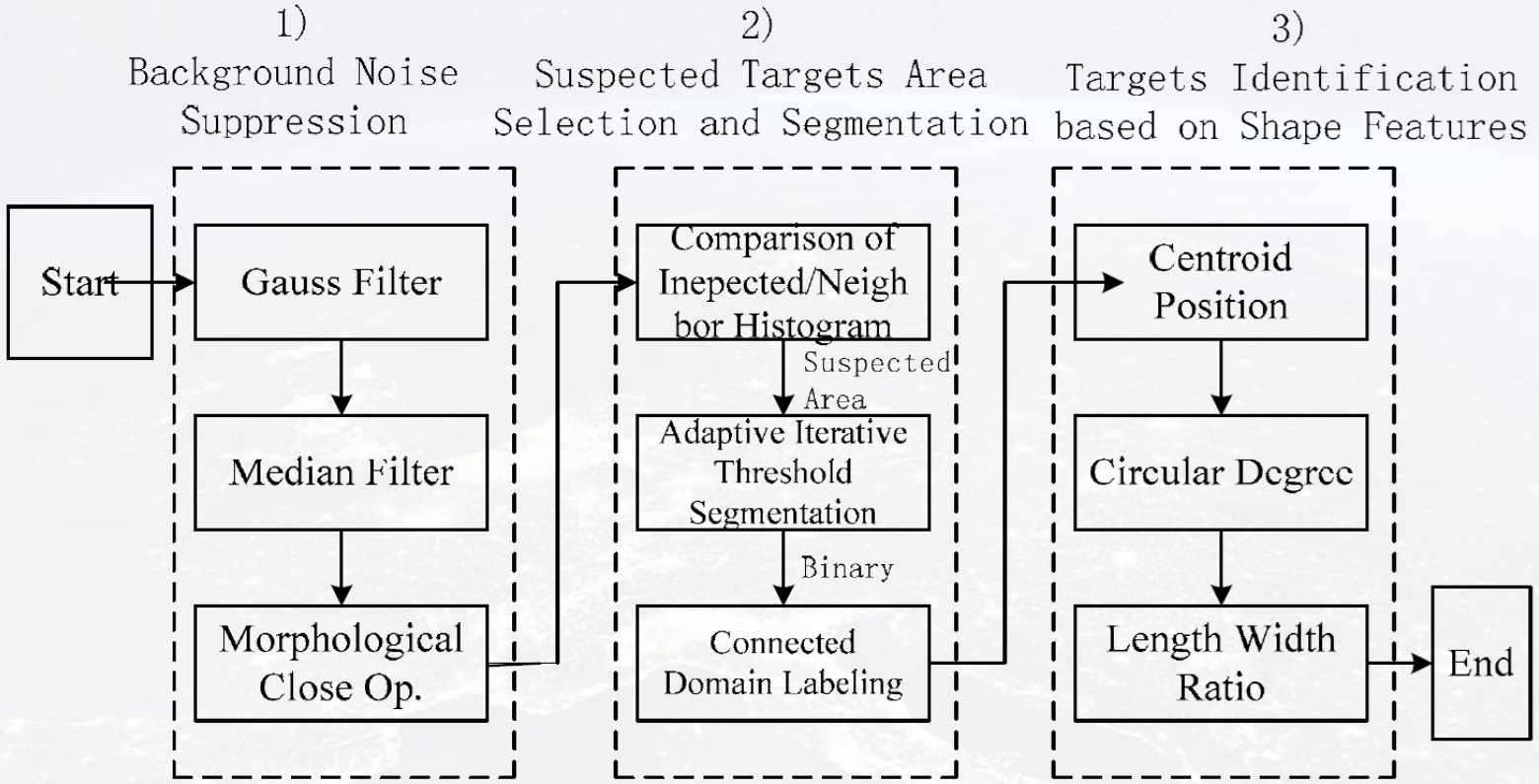
  - short revisit time to reduce the likelihood of cloud occlusion for optics applications (revisit time < 6 hours)
  - real-time problems (e.g., on-board elaboration systems) need short processing times and thus low complexity
  - ships detection with good confidence requires 5 meters spatial resolution or finer for optics applications
  - 1–2-meter resolution or even less to identify the type of ship (ship classification)

SHIP DETECTION IN S4PRO

Yang et al. (2014)		Patches of fixed size	Two ad-hoc features	Compactness and length-to-width ratio	Threshold
Yang et al. (2016)	Contrast and Fourier transform (optional)	Patches of fixed size	Local Binary Patterns	Area, length-width ratio, and compactness	Support Vector Machine
Ji-yang et al. (2016)	Gaussian filter, median filter, and morphological closing	Patches of fixed size	Adaptive iterative threshold segmentation	Length-width ratio and circular degree	

SHIP DETECTION IN S4PRO

- Ji-yang et al. (2016). 'A Real-time On-board Ship Targets Detection Method for Optical Remote Sensing Satellite'

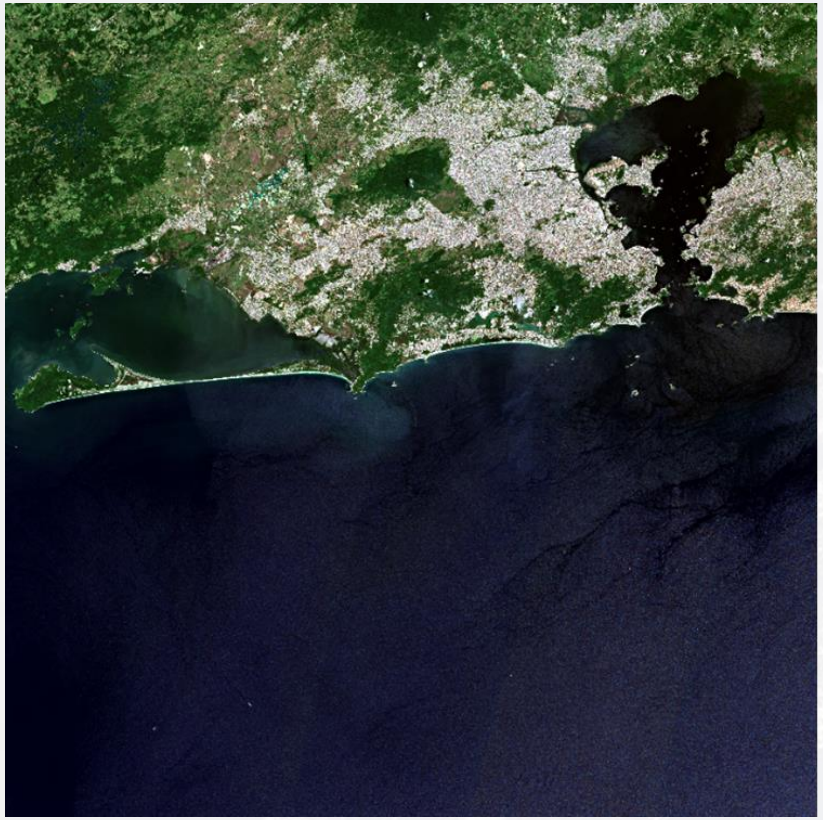


SHIP DETECTION IN S4PRO

Three real case scenarios:

Left: Rio de Janeiro (Brazil); middle: Dover (England); right: Singapore

Different conditions such as calm and rough sea, high and low density of ships, different ship sizes, presence of clouds, harbor and open-sea situations



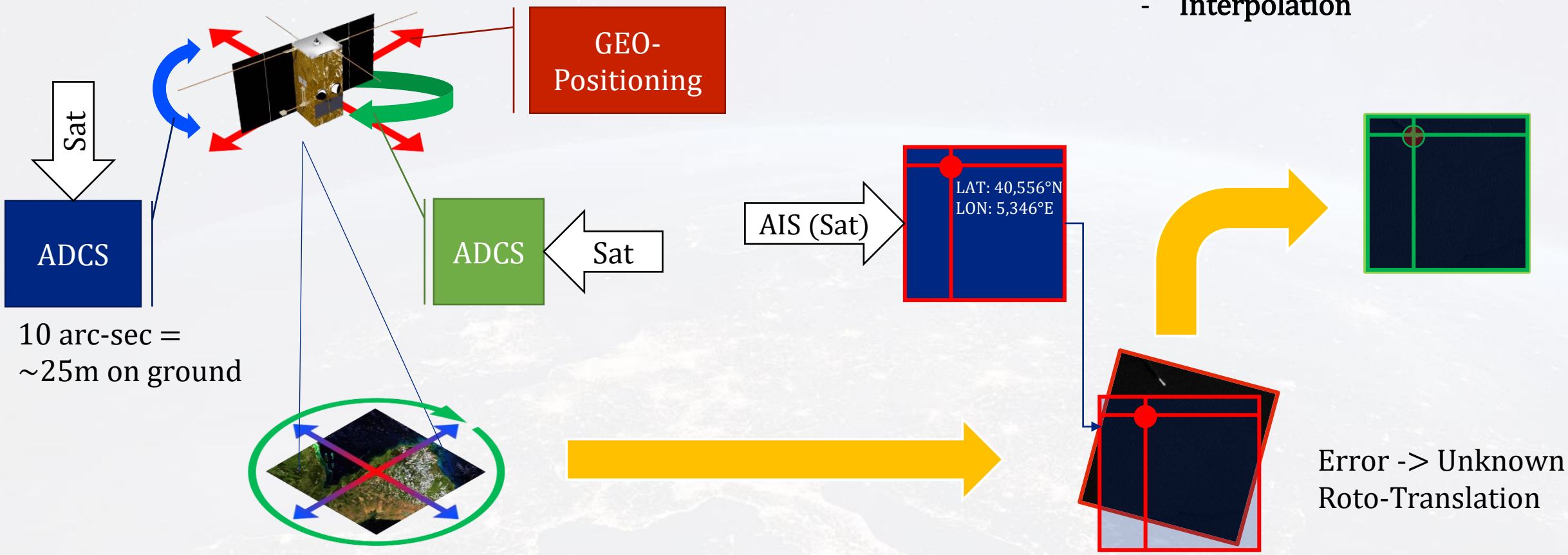
MAIN ACHIEVEMENTS

- Full End-to-End processing algorithm for Ship Detection:
  - designed for on-board processing
  - modular and scalable
  - reconfigurable
  - versatile (different inputs)

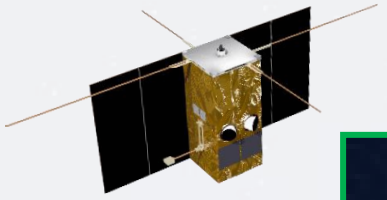
SCENES	TOTAL NUMBER OF SHIPS	NUMBER OF REAL DETECTED SHIPS	NUMBER OF MISSED SHIPS	FALSE ALARM	RECALL [%]	PRECISION [%]
Near Island	37	35	3	1	91.89	97.14
On the Sea	79	77	5	3	93.67	96.10
Near Land	71	68	7	4	90.14	94.12

- Outputs of the algorithms could be considered for direct delivery to final user (product)
- Optimized for on-board processing using technological requirements given by realistic missions and platforms
- Kernels by S4PRO could be immediately used on-board existing platforms.

GEO-TAGGING FOR AIS COUPLING

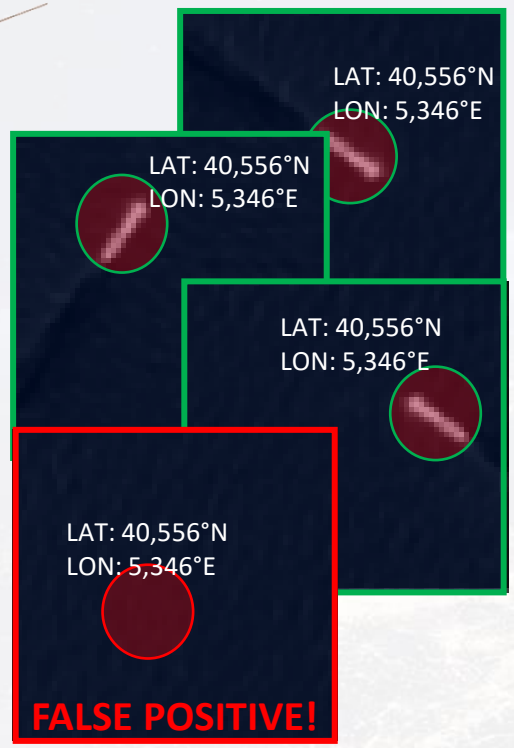


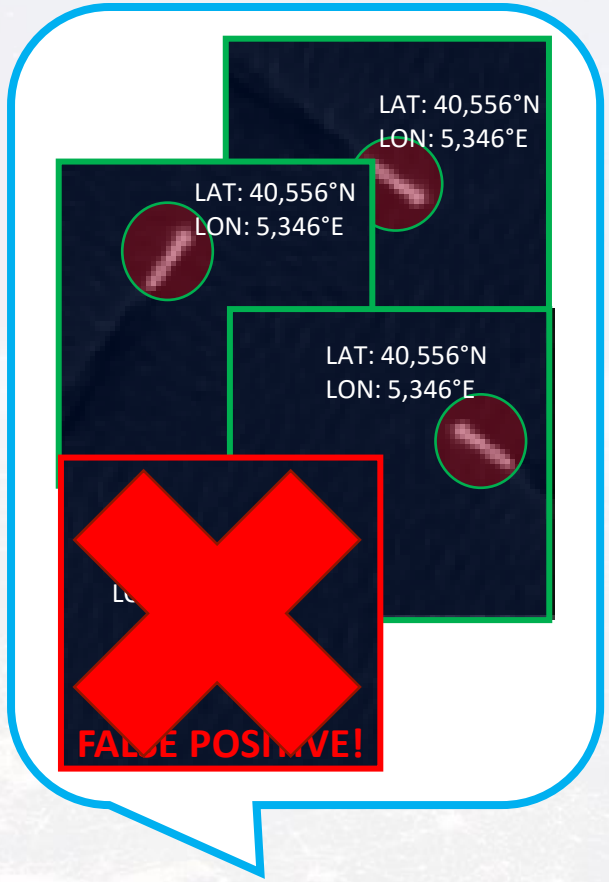
POST-PROCESS CHECK ON-GROUND



ON-BOARD PROCESSING

Low latency
Lower computational power required





ON-GROUND REFINEMENT
(false positives cancellation)

Low latency
Higher computational power required

FINAL USER

BENCHMARK AND VALIDATION

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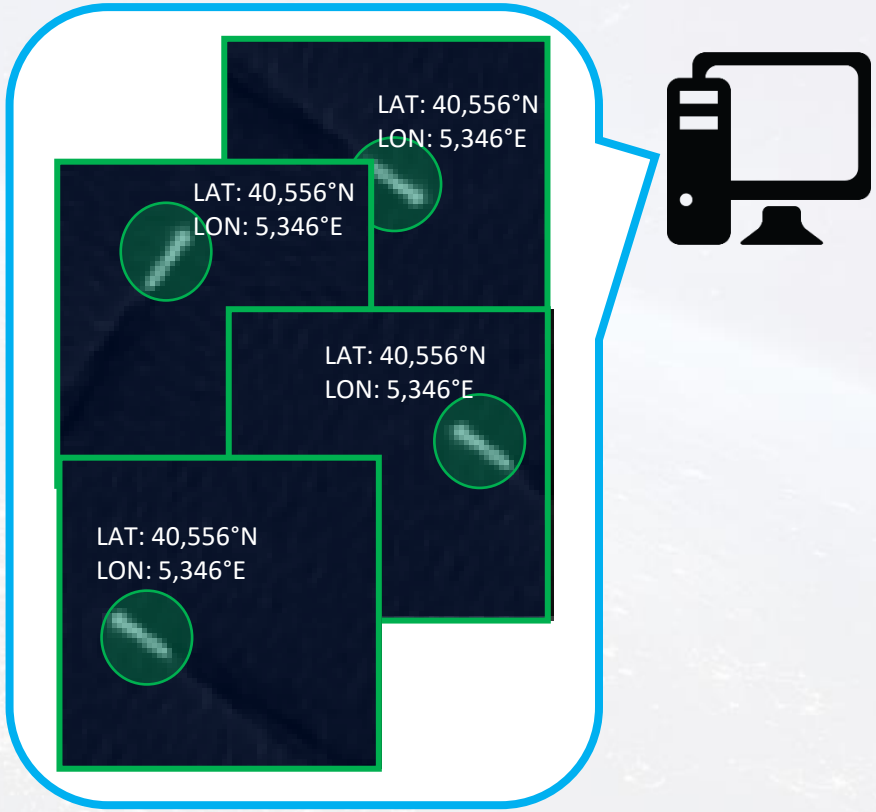
Benchmark:

COMPARISON

- Tolerance/Stability Analysis
- Ground Truth
- Algorithms Comparison
- ADCS Requirement Validation
- Latency Estimation
- Full Application Chain



THANK YOU

ANY QUESTIONS?

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