CRAFT PROSPECT
a space engineering practice

The Astral Intelligence Toolbox

A Framework for Assured On-Board Data Solutions

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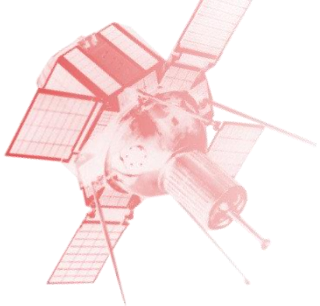

Craft Prospect Today

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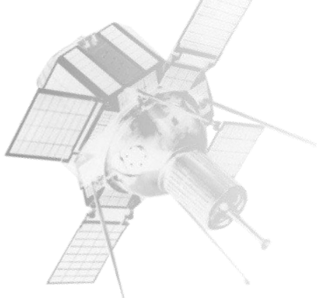
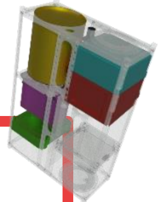
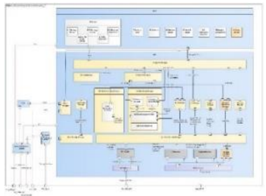


Mission & Systems Engineering



MISSION ARCHITECTURE



Core revenue & positioning

Enabling Technology Products

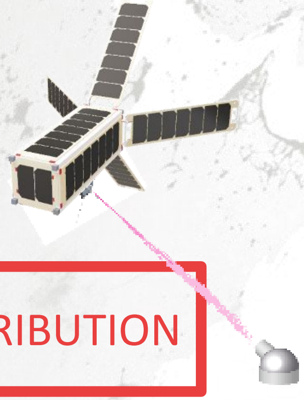
e.g. Forwards Looking Imager, Optical Beamsteering, ML Algorithms

ONBOARD INTELLIGENCE

QUANTUM TECHNOLOGY

Enables

Augmenting Emerging Services



QUANTUM KEY DISTRIBUTION

RESPONSIVE OPERATIONS

Throughout all investing in the development of systems engineering and processes

Company Timeline

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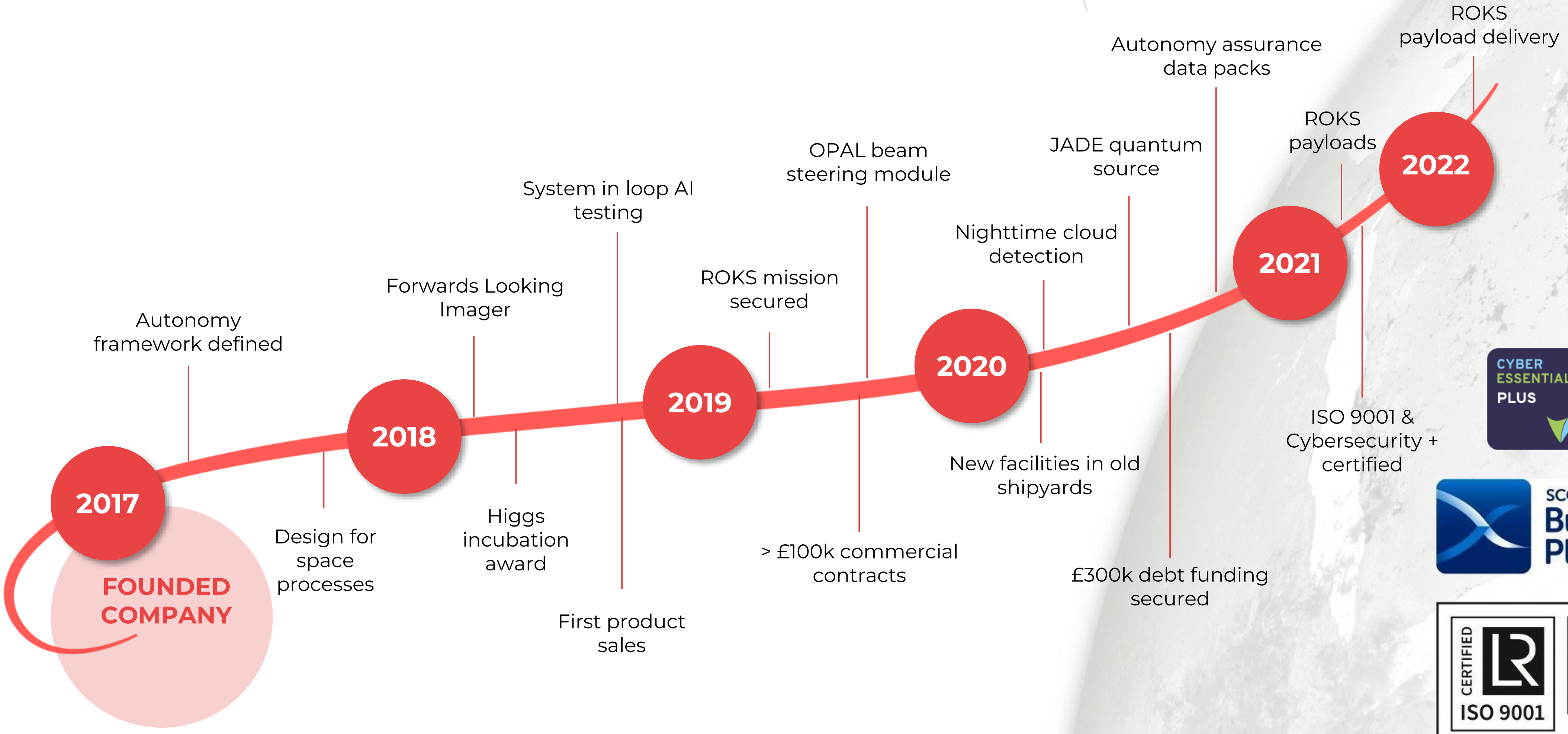


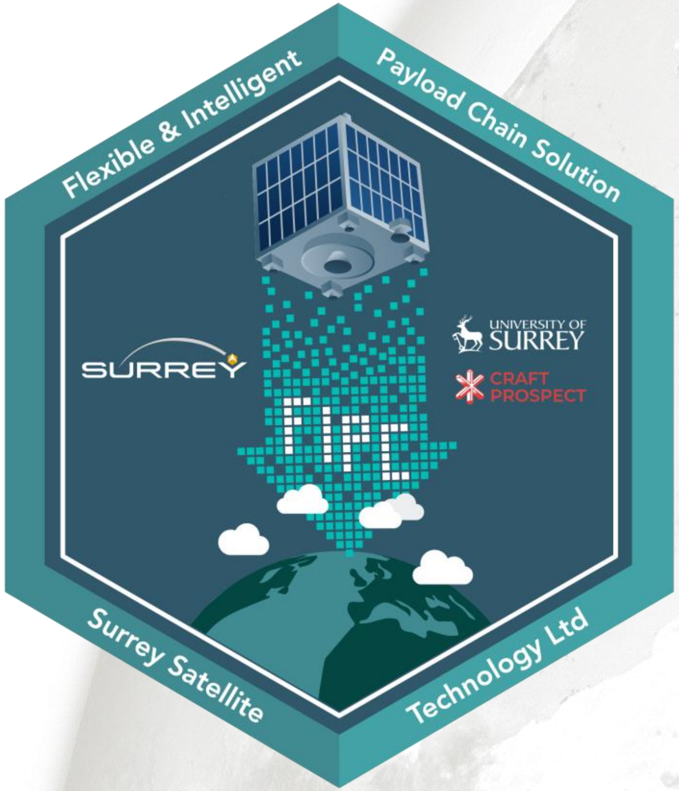
CYBER ESSENTIALS PLUS

SCOTTISH Business Pledge

CERTIFIED ISO 9001 UKAS MANAGEMENT SYSTEMS 001

InCubed FIPC Activity

- **Flexible and Intelligent Payload Chain** spacecraft architecture
- SSTL-led collaboration with Craft Prospect and University of Surrey
- Craft Prospect is consolidating its existing data processing and ML applications into a modular, reconfigurable framework, the **Astral Intelligence Toolbox**



The Need for On-Board Intelligence

- On-board AI and data processing is often seen as a “solution looking for a problem”
- But there are many challenges in institutional and NewSpace missions that could be solved by on-board intelligence
  - Handling and managing large data volumes
  - Overcoming downlink and on-board data bottlenecks
  - Responding to transient mission events
  - Adapting to mission and system changes on-the-fly

Challenges of Satellite Missions

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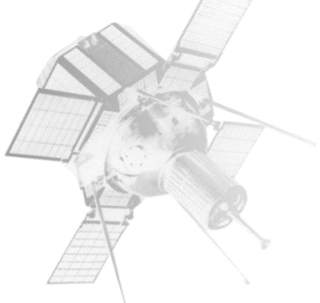
Challenges of Satellite Missions



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Issue	Benefit of On-Board Autonomy
Large data volumes leading to bottleneck in downlink	**Data product sizes can be reduced** to alleviate bottleneck; **high-value data can be identified on-board and prioritised** in downlink queue
Large data volumes obfuscating high-value data	**Data products can be tagged with rich content** such as features, value, status and changes, **enabling faster lookup** on ground or separate downlink channels
Raw data must be pre-processed on ground before dissemination to users	**Pre-processing can be performed on-board** while waiting for ground station pass, **eliminating equivalent latencies** on ground
Operational responses to features of interest in payload data are very high latency (space-ground-space)	**On-board information extraction enables near-real-time decision making** and responsive tasking, **closing operational feedback loop** on-board
Sensor degradation with time	**Anomaly detection can identify defects** from nominal conditions and trigger **automated calibration, validation and adaptive optics**

Challenges in On-Board Autonomy

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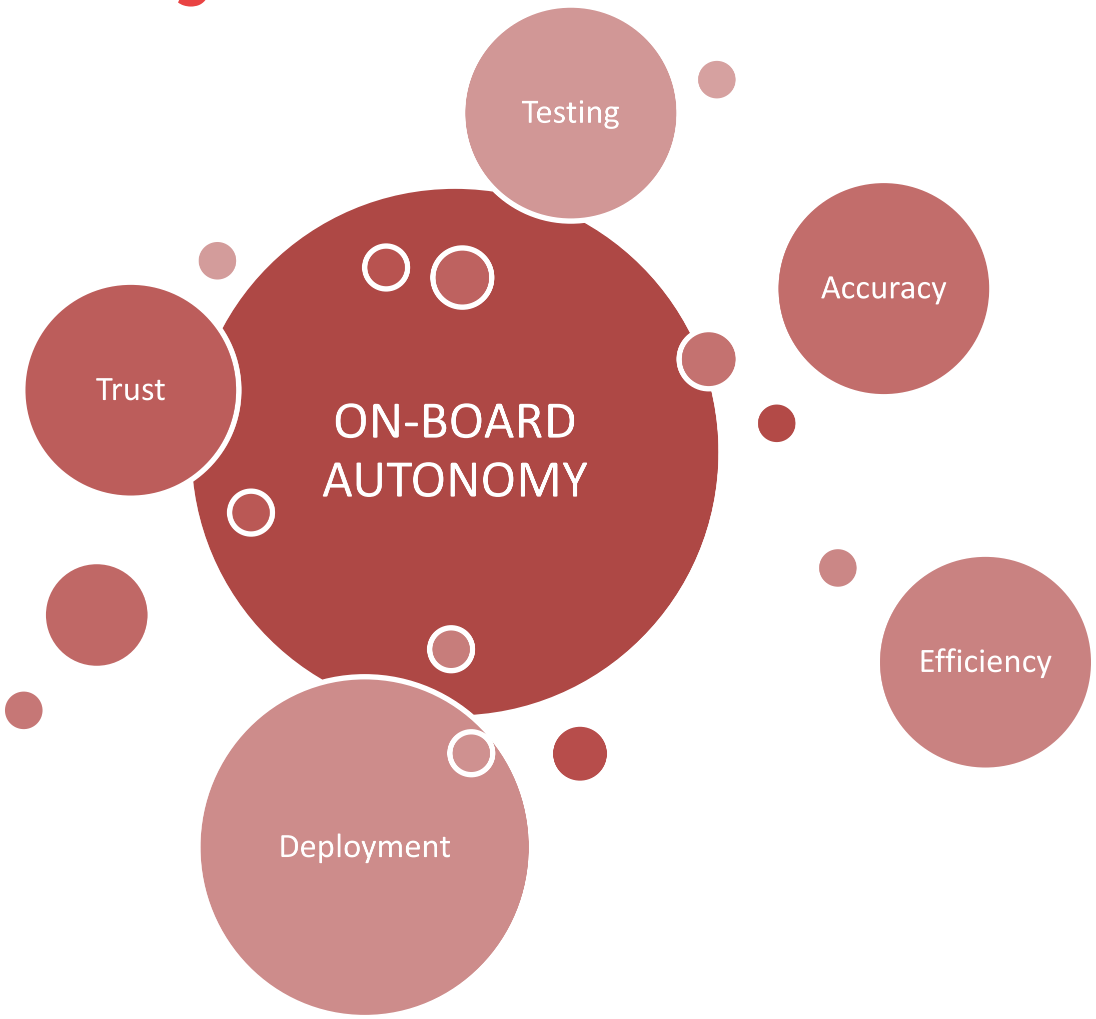

Challenges in On-Board Autonomy

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Challenge	Solution
Fault-tolerance of AI, especially in mission-critical applications	Hardware and software redundancy, ML-specific FDIR
Balancing latency, accuracy and power requirements	Optimise models for embedded processing using available tools. Test in representative simulations.
Risk of data loss when autonomously processing and prioritising data	Focus on lossless techniques, e.g. data prioritisation, compression. Minimise loss risks through software assurance
Adapting to different mission configurations, e.g. platform, payload, customer, application	Modular, component-based framework. Use of MBSE to flow requirements through to functional and logical design
Trust that outputs and decisions are accurate and truthful, will not harm life or mission assets	Assurance during development time and in real-time (e.g. autonomy supervisor)
Exhaustive testing and documentation of test cases and scenarios	Bounding of autonomous decision outcomes. Testing in simulated environments

Creating a Solution: Driving Requirements

1. Solve the problem: focus on the main challenges (management, throughput, responsiveness, dissemination)

2. Configure easily to new applications, platforms and instruments

3. Assured operation: quantified performance and bounded operating conditions

4. Easily upgradeable as technologies and understanding evolve

Creating a Solution: The AITB Philosophy

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Rapid insights: generate information and insights which would otherwise require human input

Modular approach: enable components to be individually tested, upgraded and distributed

Easily configurable to different use cases: adjust components to target different features of interest, utilise different hyperspectral bands and create new data products

Platform agnostic: run on frameworks such as Unibap's SpaceCloud, SSTL's Flexible & Intelligent Payload Chain (FIPC), embedded Linux and bare metal

Simplified assurance: flow down mission safety and assurance requirements to components using proven processes and document system using MBSE

Mission tailored: quickly configure bespoke processing chains and optimise for different missions and applications

Focus on outcomes over algorithms: focus on the integrated solution, with individual components operating together to meet the needs of mission stakeholders

Aligned to CCSDS Mission Operations Services Concept

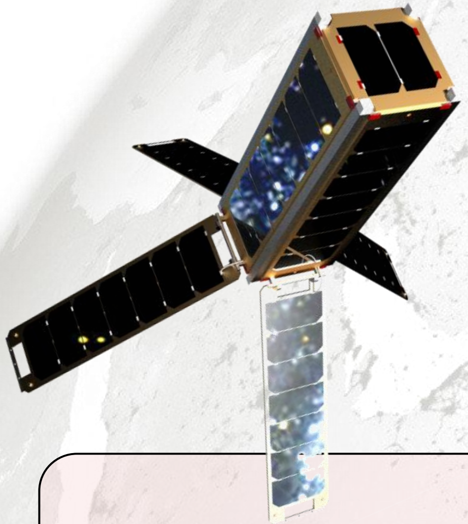
The Astral Intelligence Toolbox

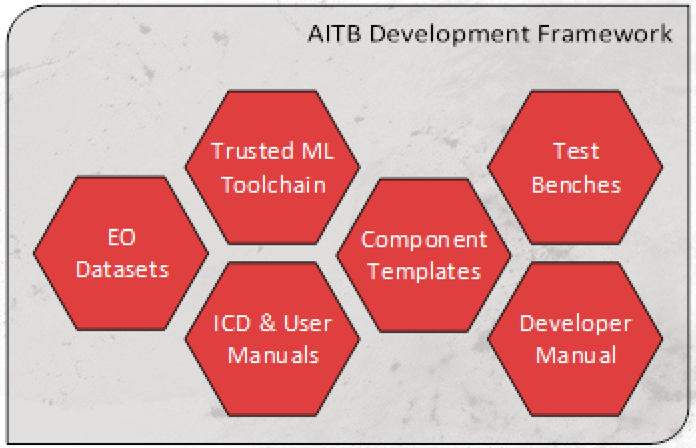
Development framework

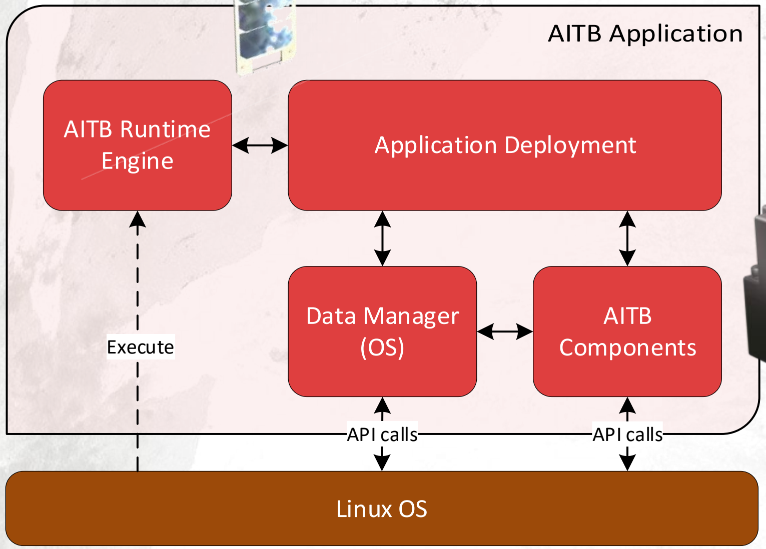
- Component template and generation
- MBSE and automated documentation
- Trusted ML toolchain
- Library of datasets and models
- HIL simulation test bench

Deployment framework

- Component-based software library
- Wide ML runtime library support
- Decoupled visualisation and profiling components
- Swappable platform-specific components



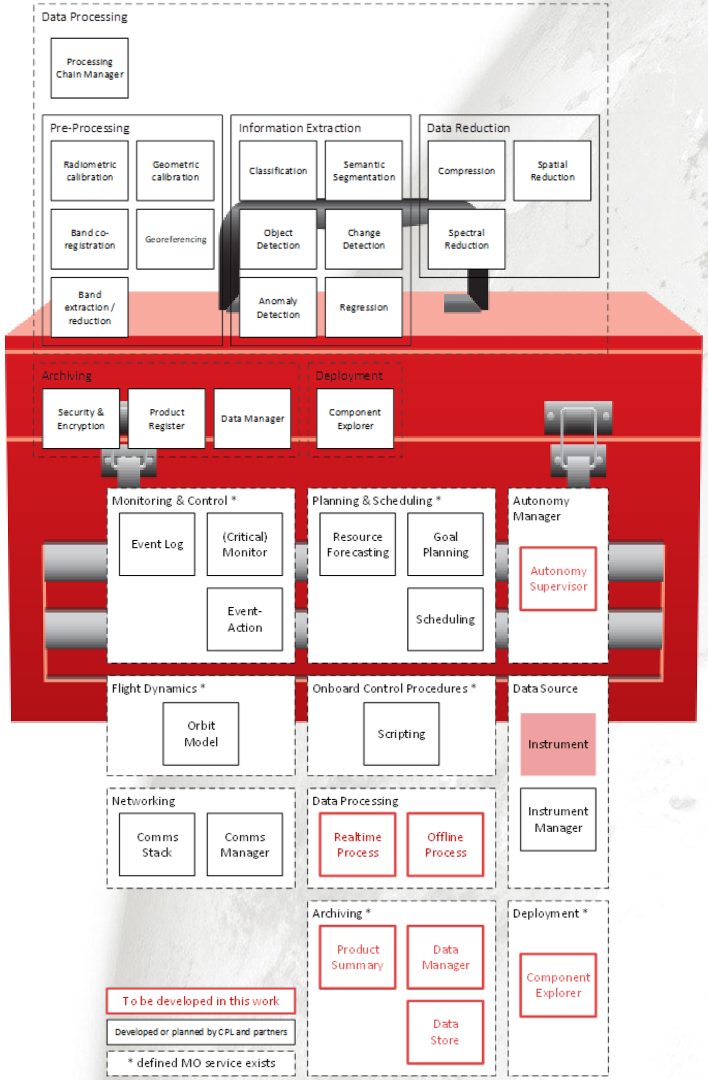




The Astral Intelligence Toolbox

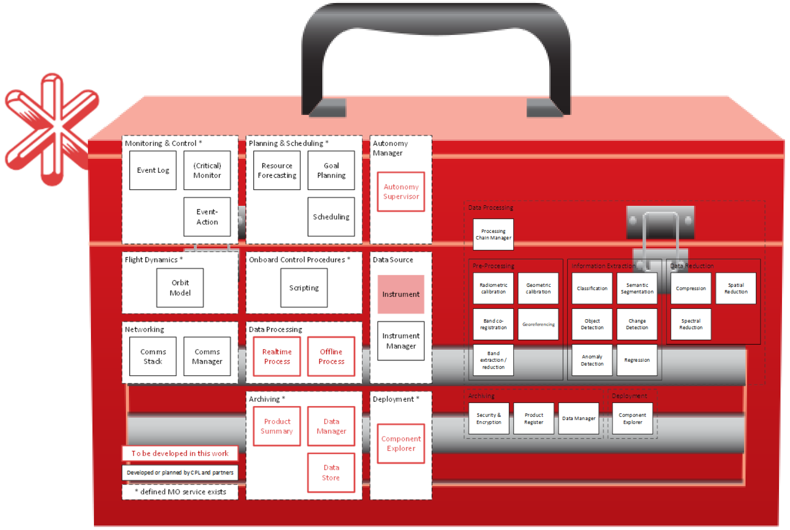
Data autonomy: processing, information extraction and management

- Correction + calibration
- Machine learning
- Product creation
- Compression + reduction
- Storage + downlink optimisation



Mission autonomy: real-time autonomous mission operations

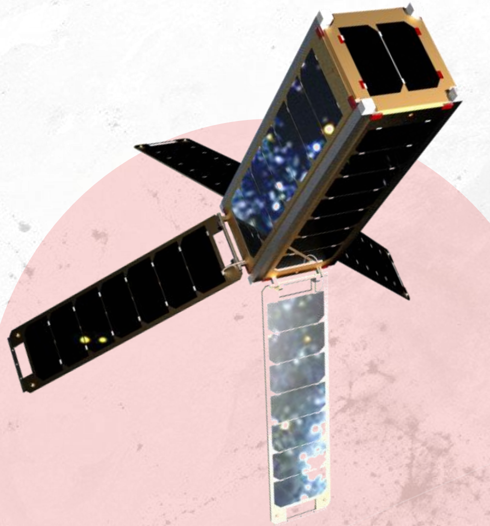
- Goal-based planning
- Resource forecasting
- Real-time scheduling
- Mission-critical tasking
- Autonomy supervision



AITB

FORWARDS LOOKING IMAGER

- Real-time advance sub-satellite knowledge
- Enables cloud-sensitive mission activities

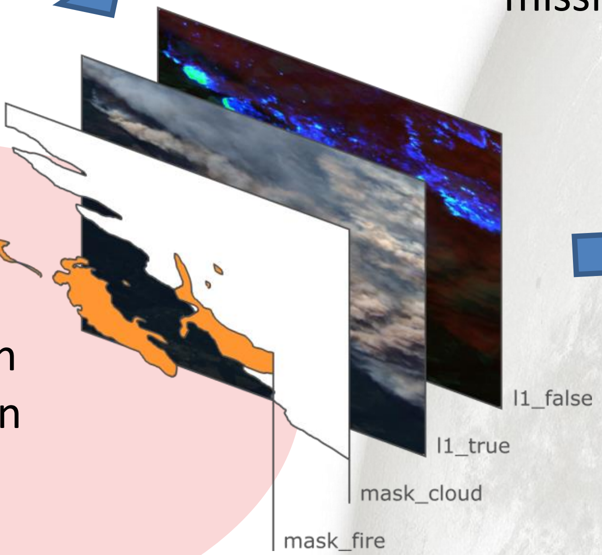


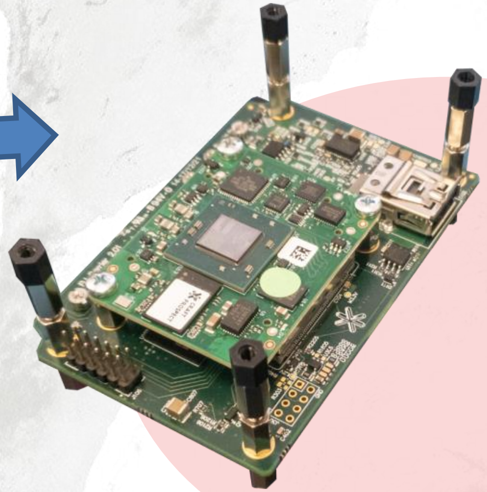
Autonomous Mission Architecture

- Complete solution
- Responsive
- Safe + trusted

On-board applications

- Cloud masking
- Feature detection
- Calibration and validation
- Product and alert creation
- Hyperspectral data reduction
- Downlink queue optimisation
- **Assured and trustworthy**

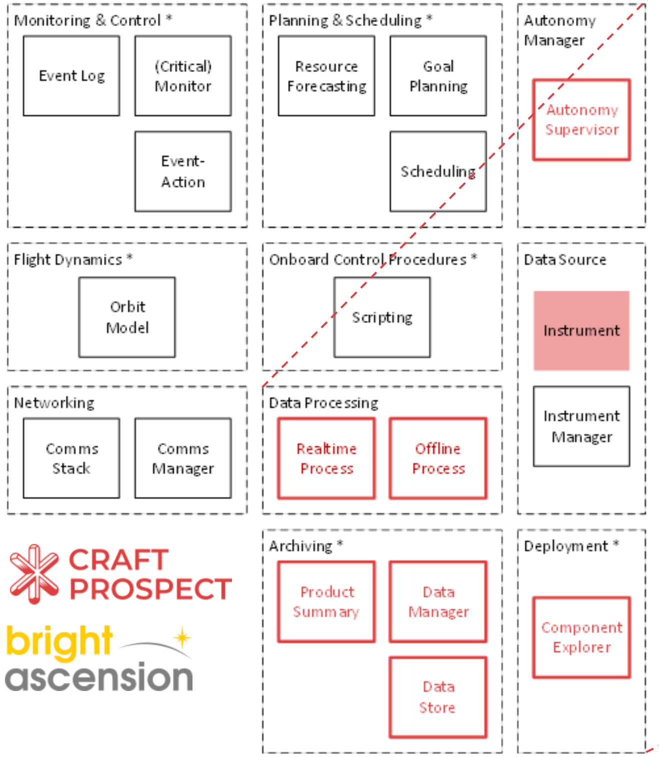




Processing Payload (bespoke or third-party)

- Run AITB applications
- Interface with instruments and OBC

Framework



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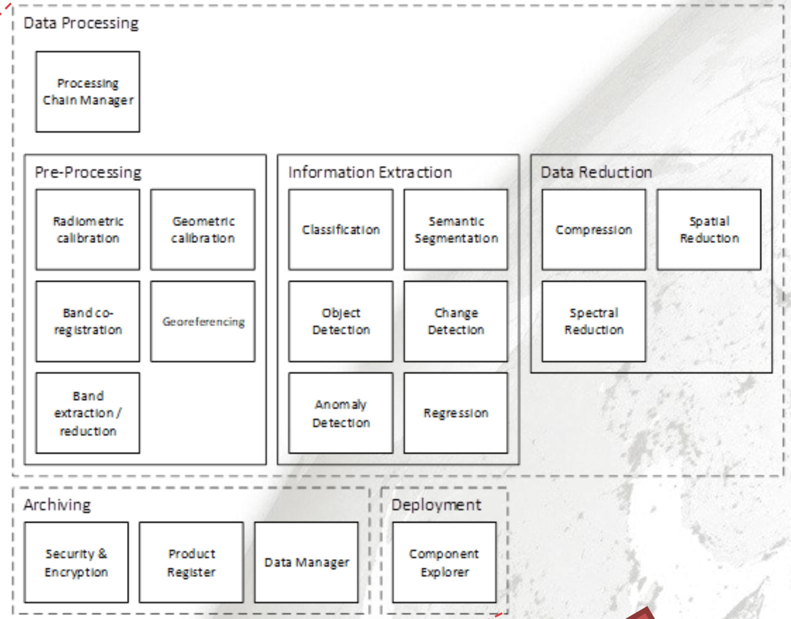
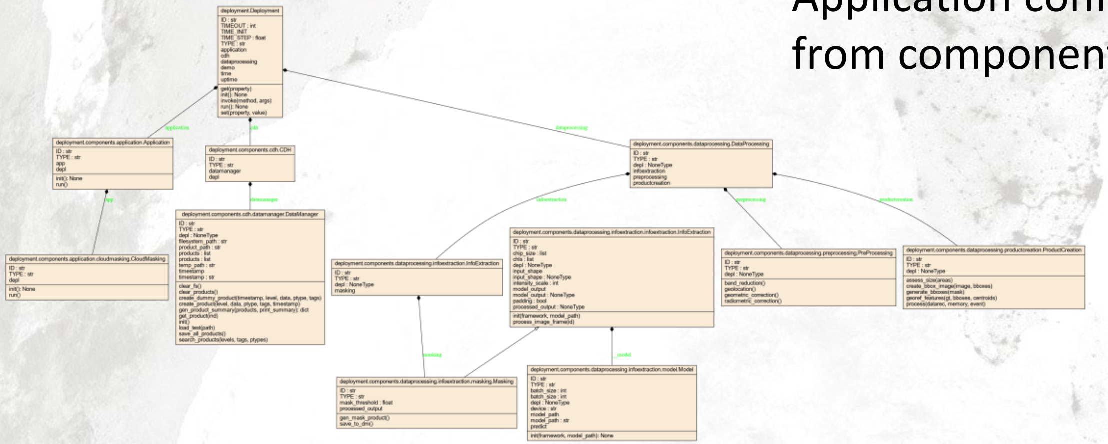
bright ascension



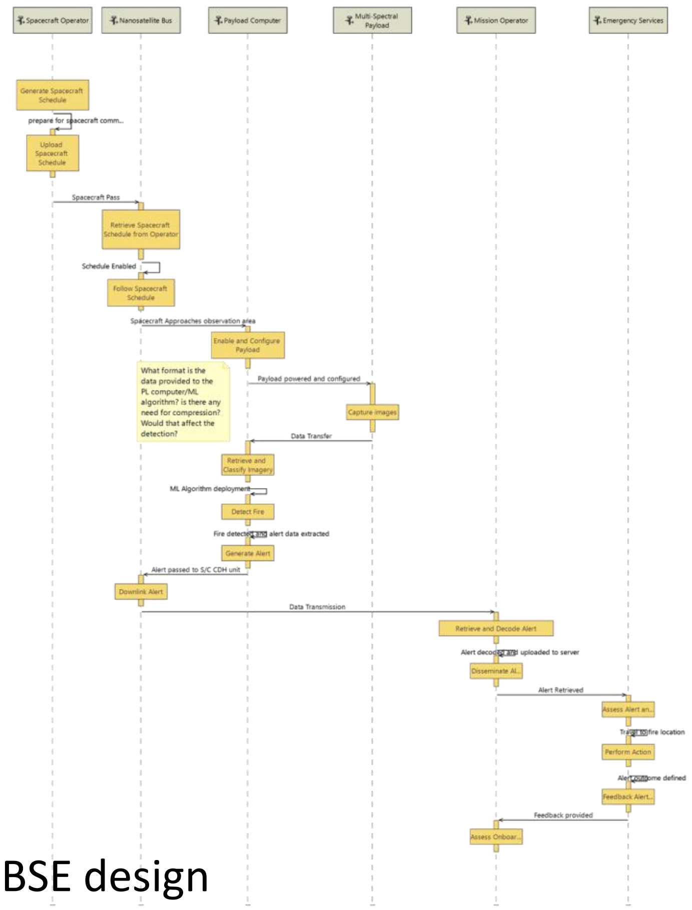
Data processing, information extraction and management components



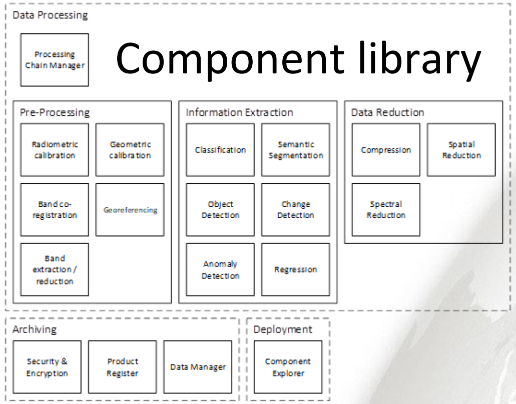
Application configured from components

Mission autonomy and data processing component library

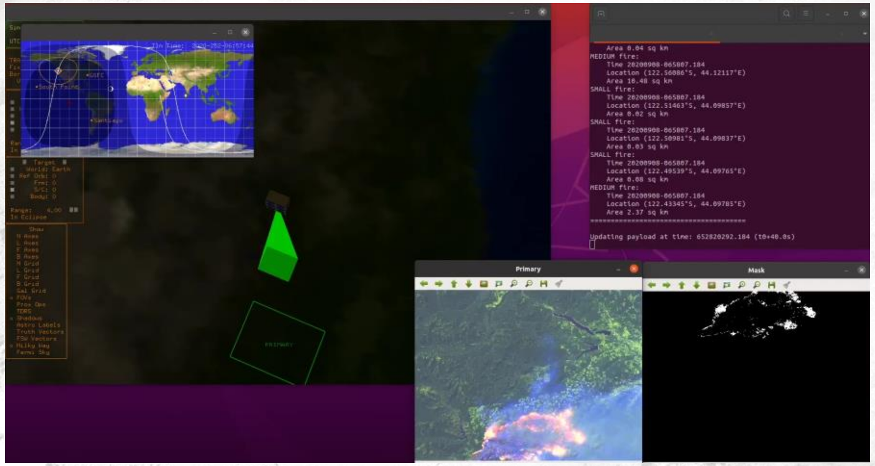
Development Tools



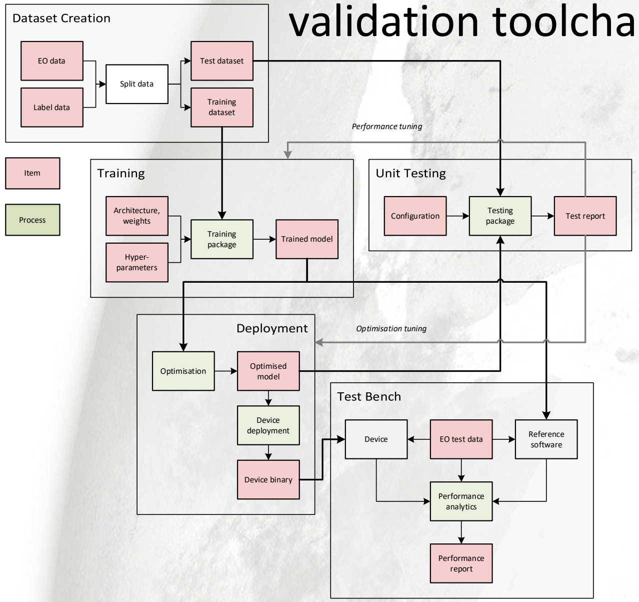
MBSE design

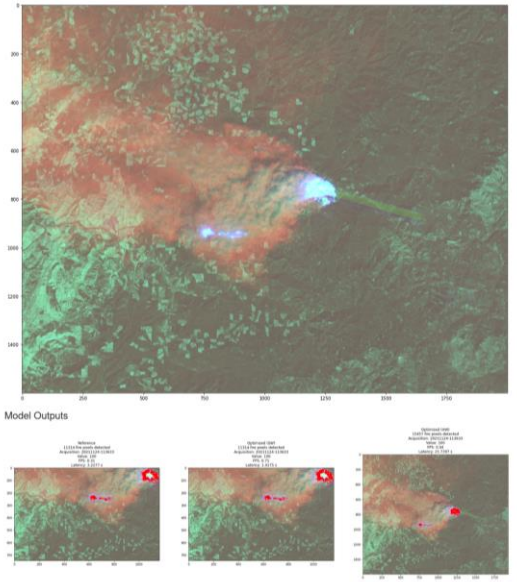


Mission simulator



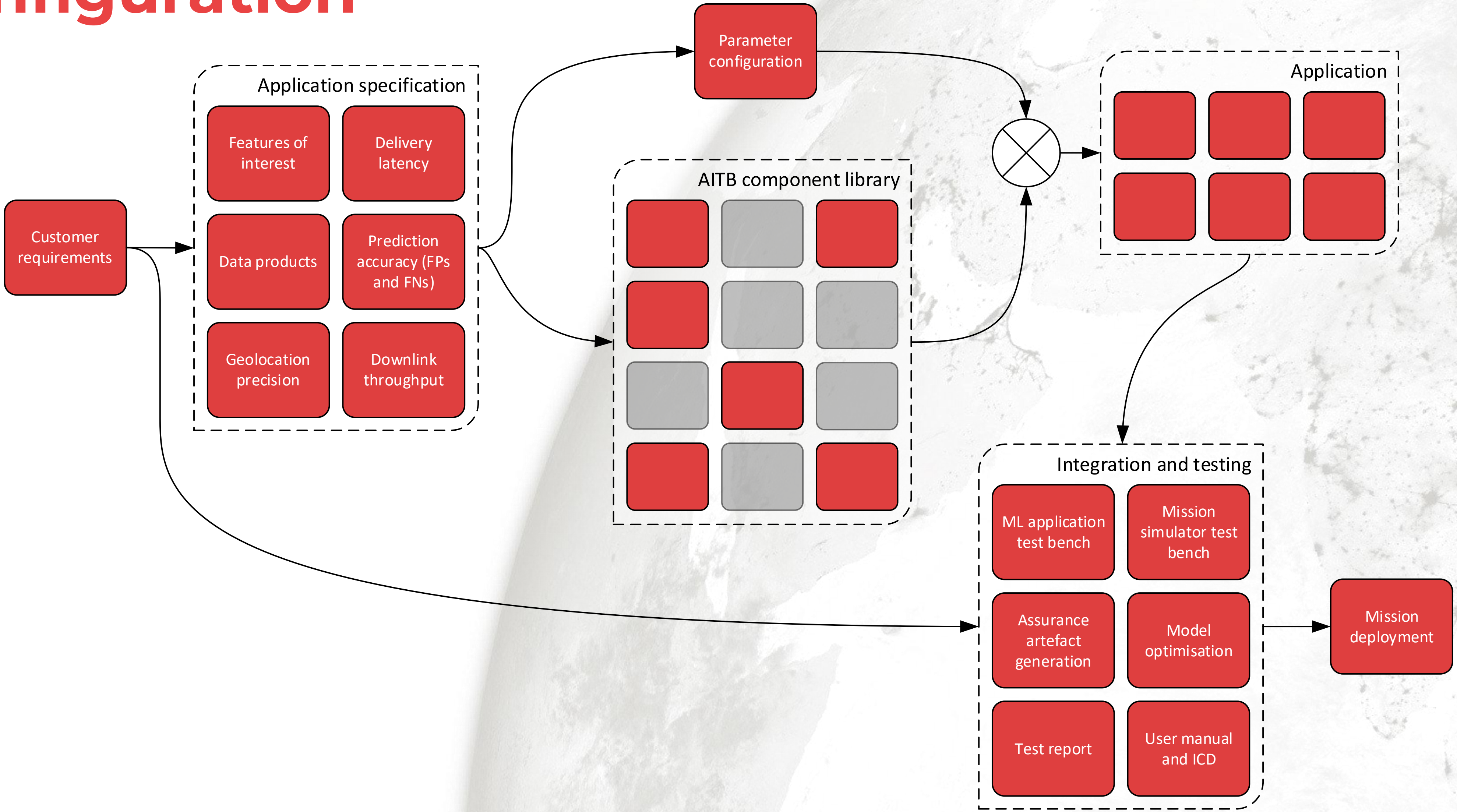
ML development and validation toolchain



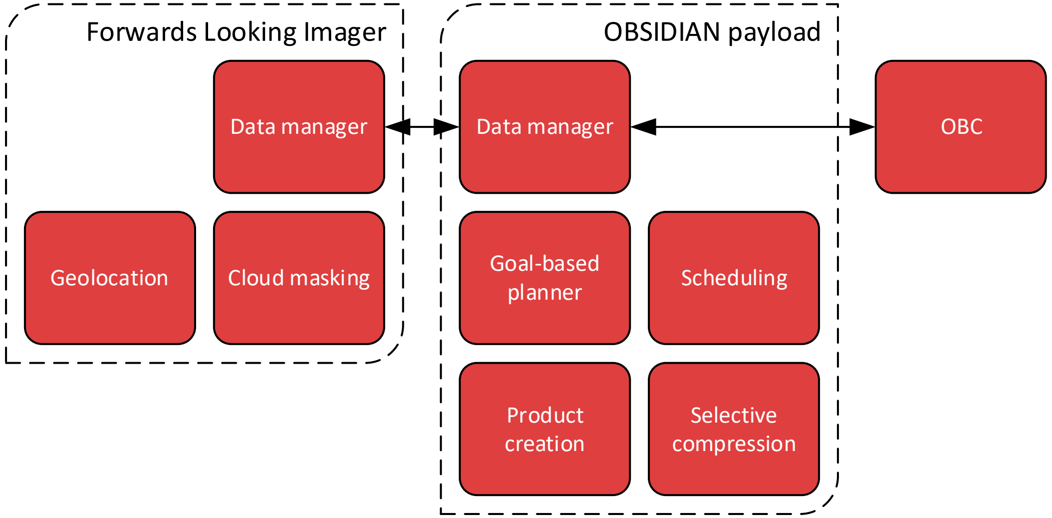


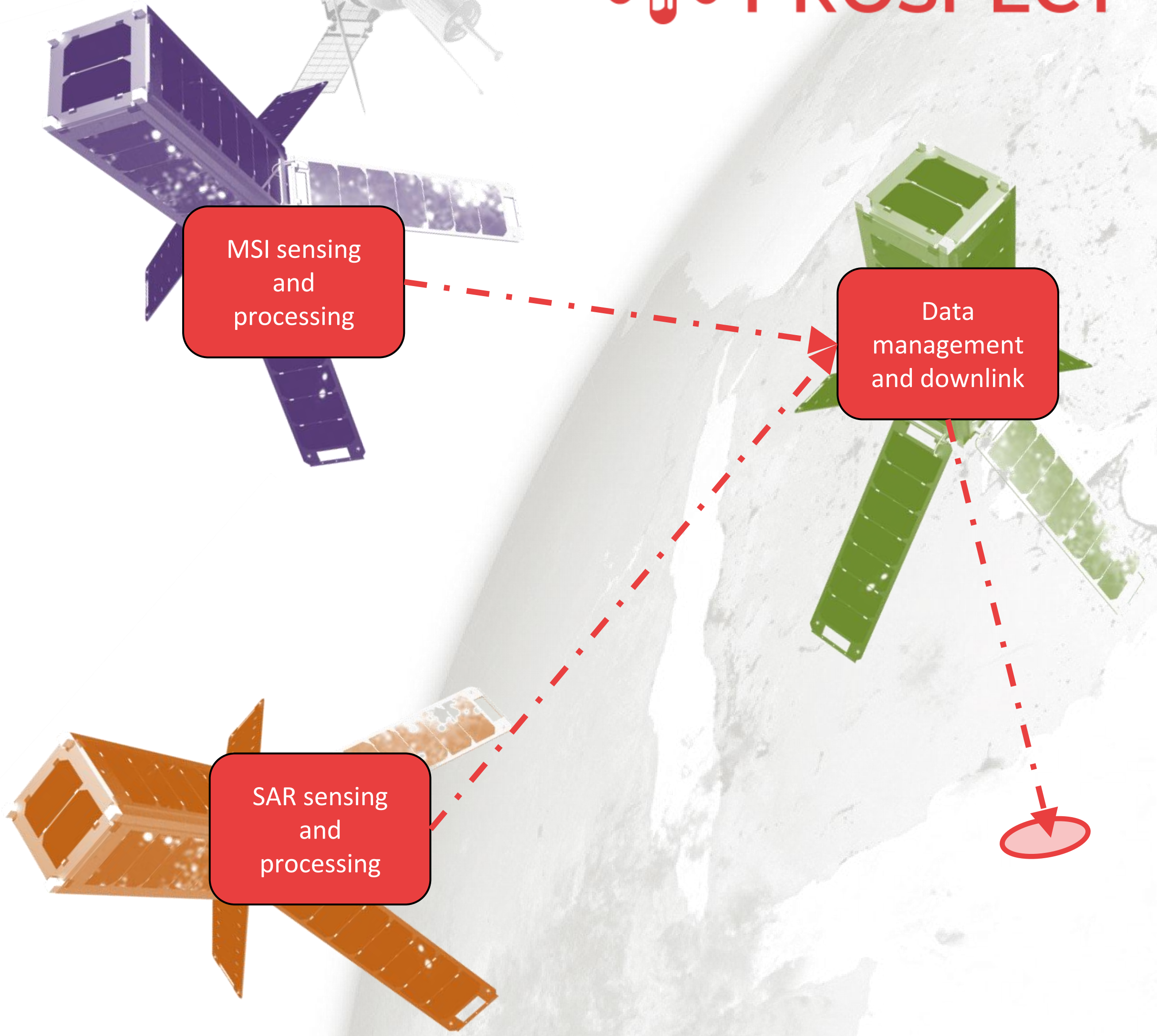
ML component benchmarking

Application Specification & Configuration



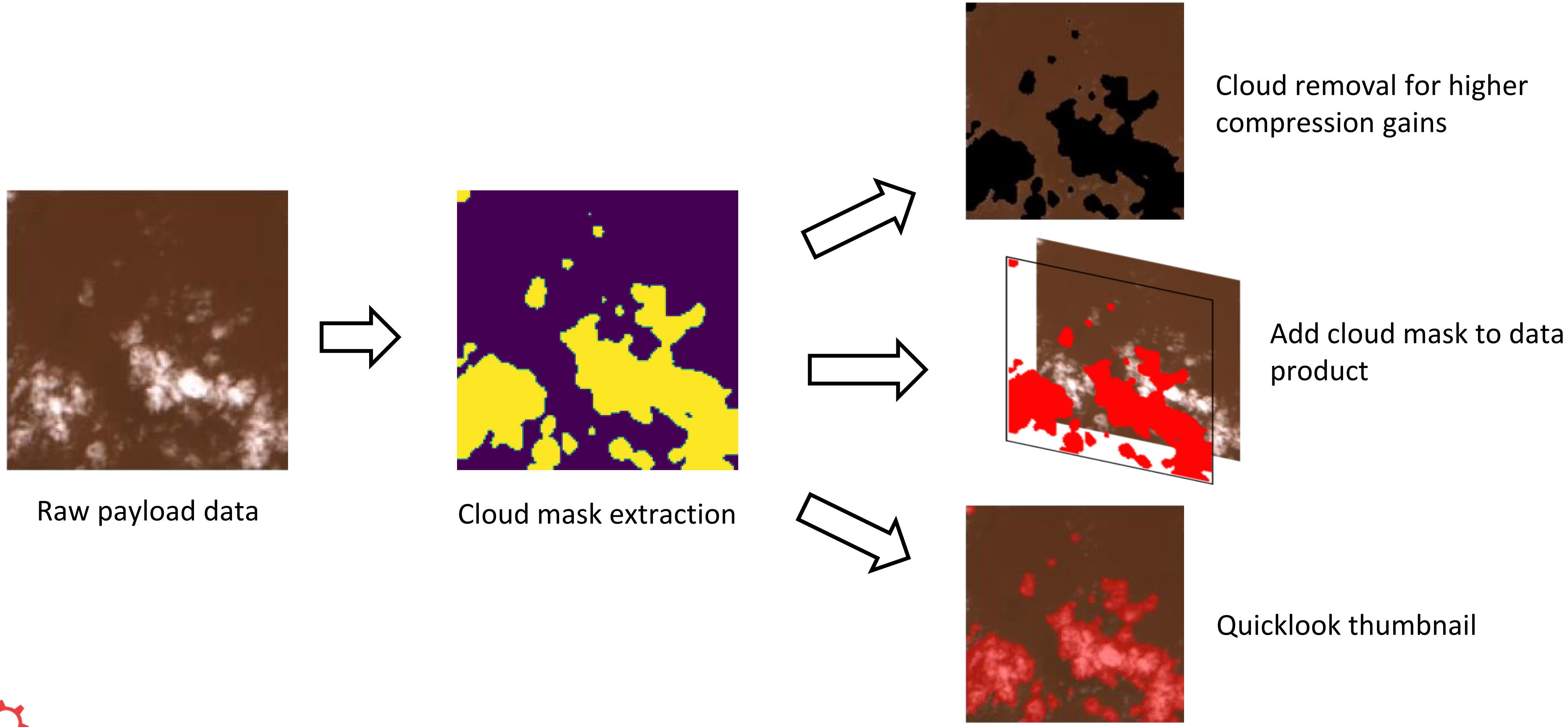
Distributed Applications





Example Applications

AITB Sample App: Cloud Masking



AITB Sample App: Feature Alerting (Wildfires)

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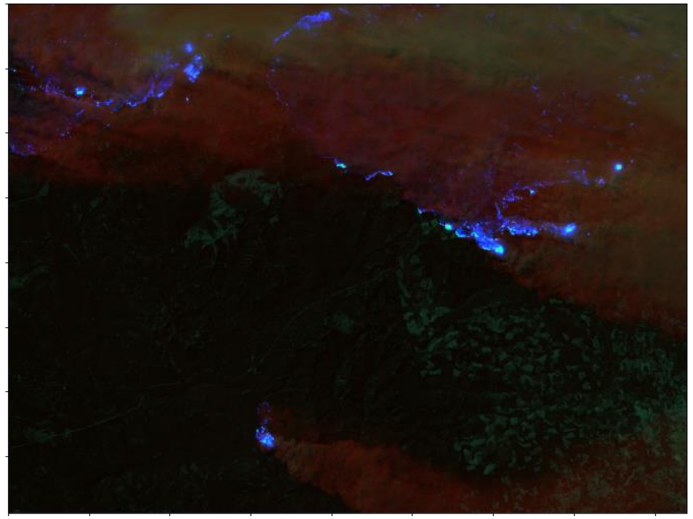
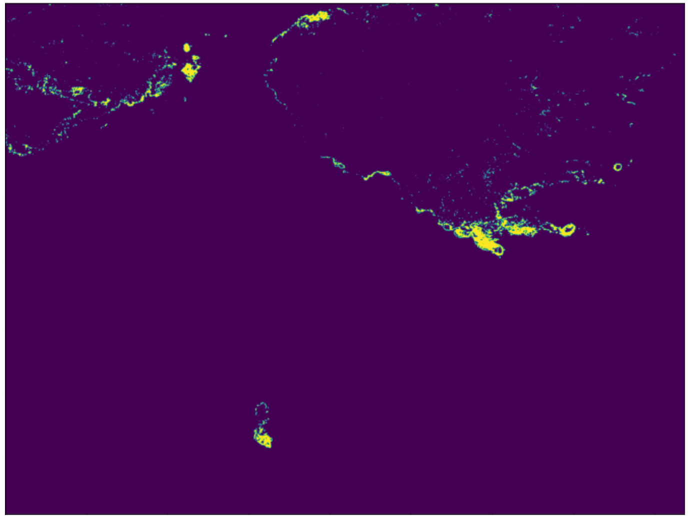
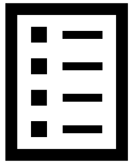


Raw payload data

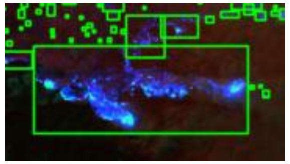


Fire mask extraction

Alert, < 100 KB



Detailed report, ~ 100 KB

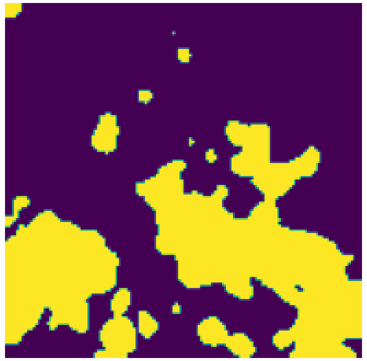


Spatial products
Thumbnails, 0.1 - 100 KB
Fire mask, 6 KB
Multispectral image, 30 MB

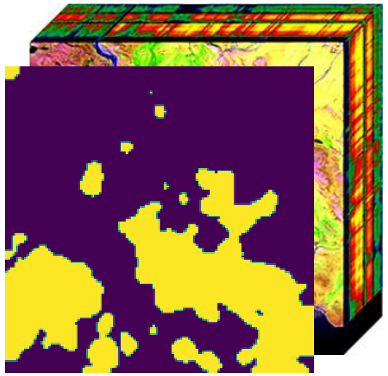
Product creation

AITB Sample App: Hyperspectral Data Reduction

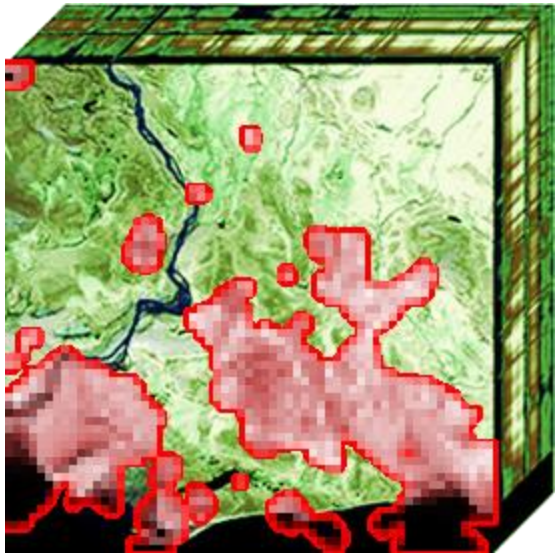
Raw payload data



Cloud or feature mask extraction



Add cloud mask to datacube



Selective compression:

- High-value regions preserved
- Low-value regions lossy-compressed

Benefits:

- Overcomes downlink bottleneck for high-volume data
- High-value regions of data are preserved (lossless compression)
- Low-value regions of data are lossy compressed
- ML powered: can use multiple masks with different band combinations

Compression gains of 5-40x compared to pure lossless compression

AITB Sample App: Selective Compression

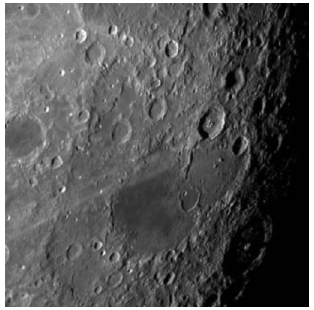
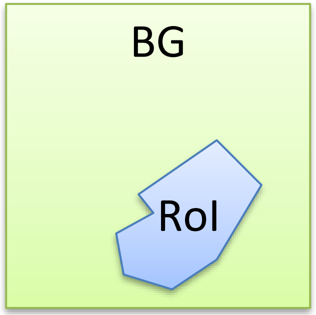
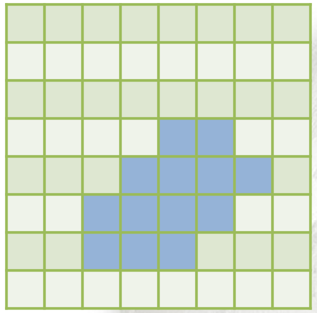


Image data with region of interest (RoI)



Extract RoI using ML or CV



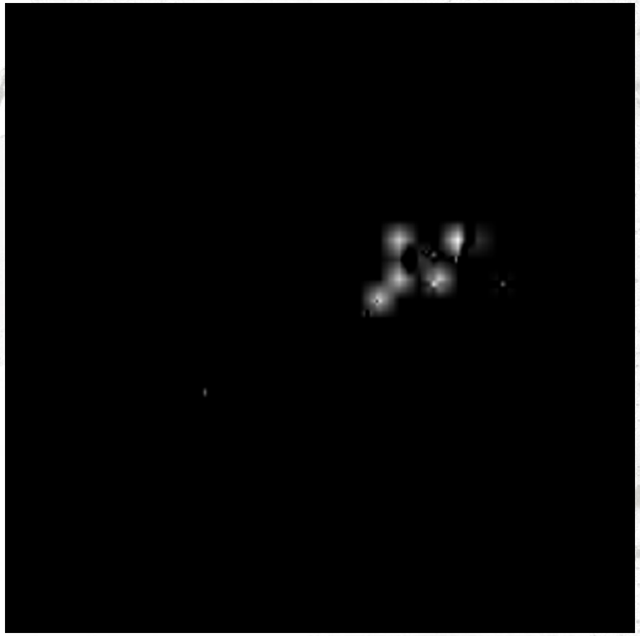
Discretise into blocks

Benefits:

- No loss of data in high-value regions
- Low-value regions retained for context
- Lossless data can be prioritised in DL ahead of lossy
- Lossy compression parameters can be tuned

Method	Description	Avg comp. ratio*
Grid	Custom grid-based approach	10
SPIHT	Compress DWTs into bitstream	11
CCSDS	Based on CCSDS-122.0-B-1	19

*Tested on 5-channel multispectral images



Demo on CCSDS test image

AITB Planned Applications

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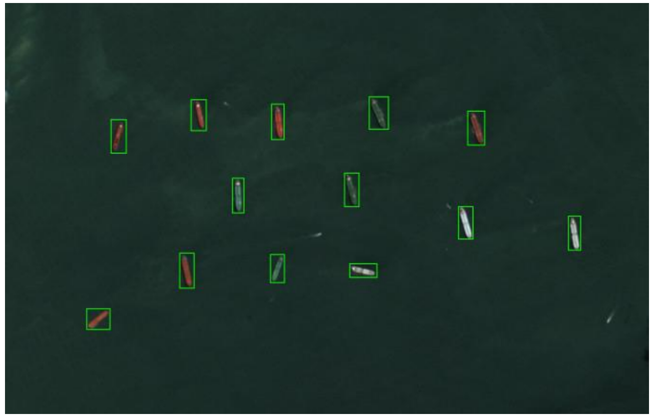
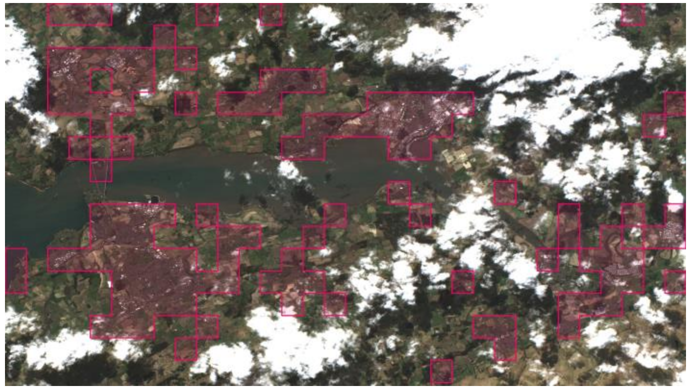
- Land cover mapping and product creation - multispectral
- Ship detection and tracking – SAR
- Parallax cloud imaging – FLI Gen2
- Digital elevation model generation



Ship detection

Ship dataset augmentation with GAN

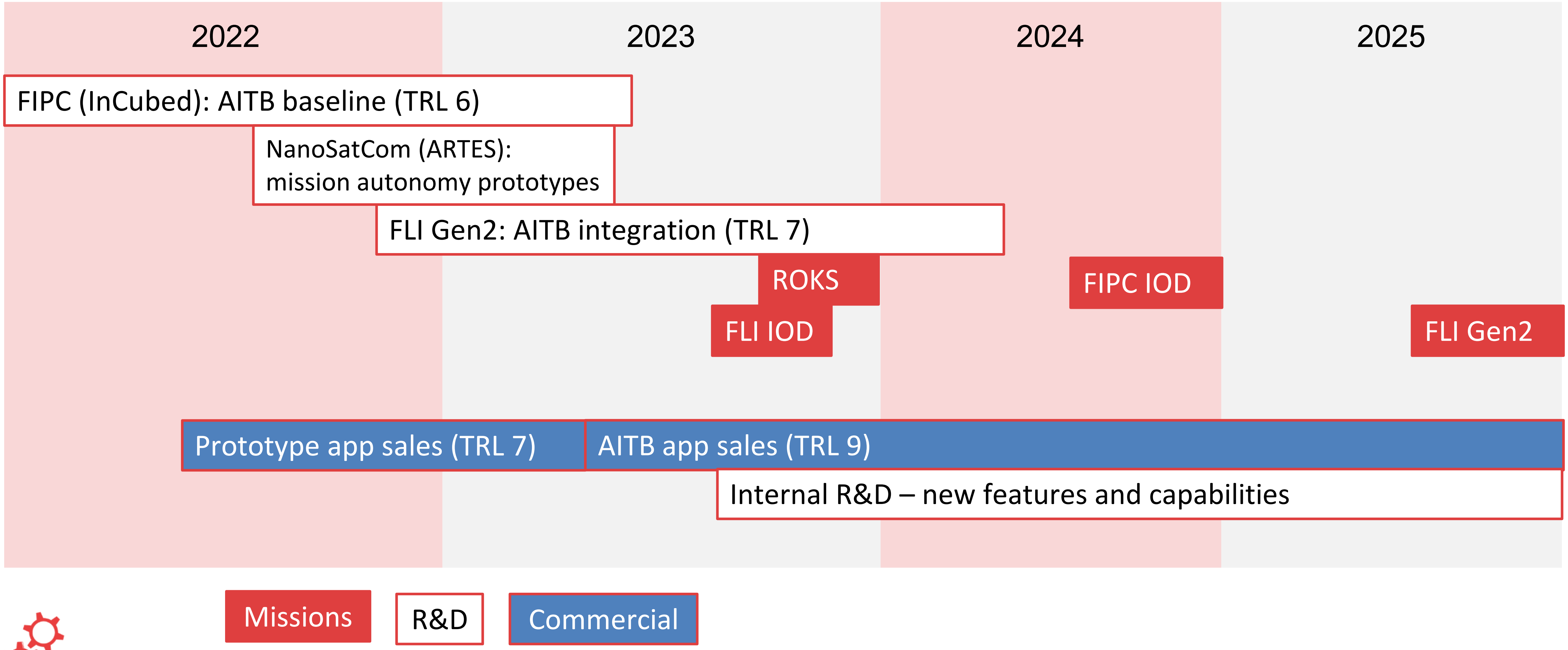


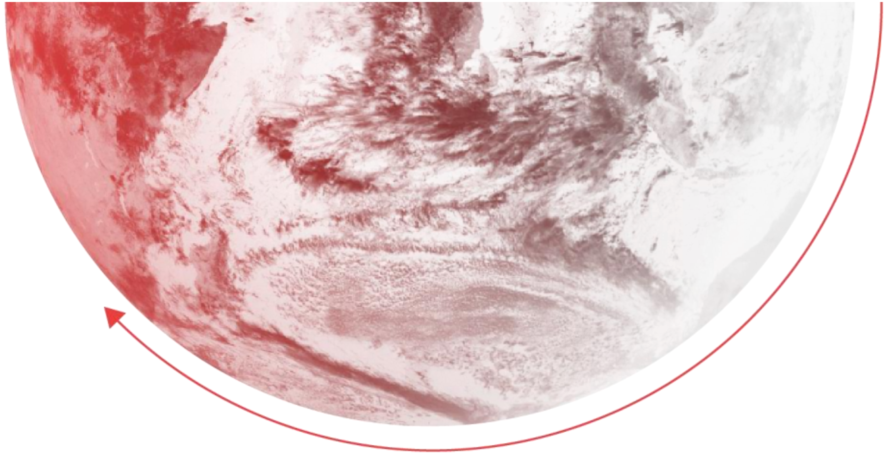
Urban fabric classification - Edinburgh

AITB Development and Demo Timeline

Date	Event
December 2022	InCubed FIPC CDR
March 2023	Demonstration of AITB apps on CPL test bench (TRL 6)
April 2023	Demonstration of AITB apps on SSTL ACP board (TRL 7)
May 2023	InCubed FIPC final review
Q3 2023	In-orbit demo of cloud masking model (KAUST-SAT)
Q4 2023	In-orbit demos of FLI (day and night-time)
2023	SpaceCloud IODs (in discussion)
2024	SSTL IODs (planned)
2026	AITB-powered FLI Gen2 IOD

AITB Roadmap





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Thank you

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