IS SPACE READY FOR THE QUANTUM LEAP?

QUANTUM @ THALES ALENIA SPACE

TOMMASO CATUOGNO

MATTIA VERDUCCI

Date: 06/09/2023
Ref: xxxxx
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PART 1:
THALES ALENIA SPACE & THE SPACE SECTOR

THALES ALENIA SPACE – COMPANY OVERVIEW

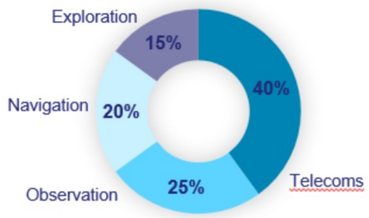
/// Thales Alenia Space delivers cost-effective solutions for telecommunications, navigation, Earth observation, environmental management, exploration, science and orbital infrastructures

JOINT VENTURE

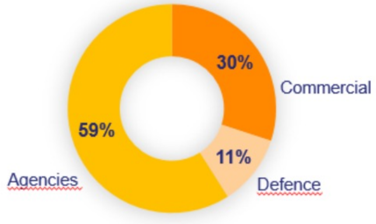
ThalesAlenia Space
a Thales / Leonardo company

THALES (67%)
LEONARDO (33%)

PER ACTIVITIES



PER MARKET



8,000
EMPLOYEES

2,15
BN € SALES

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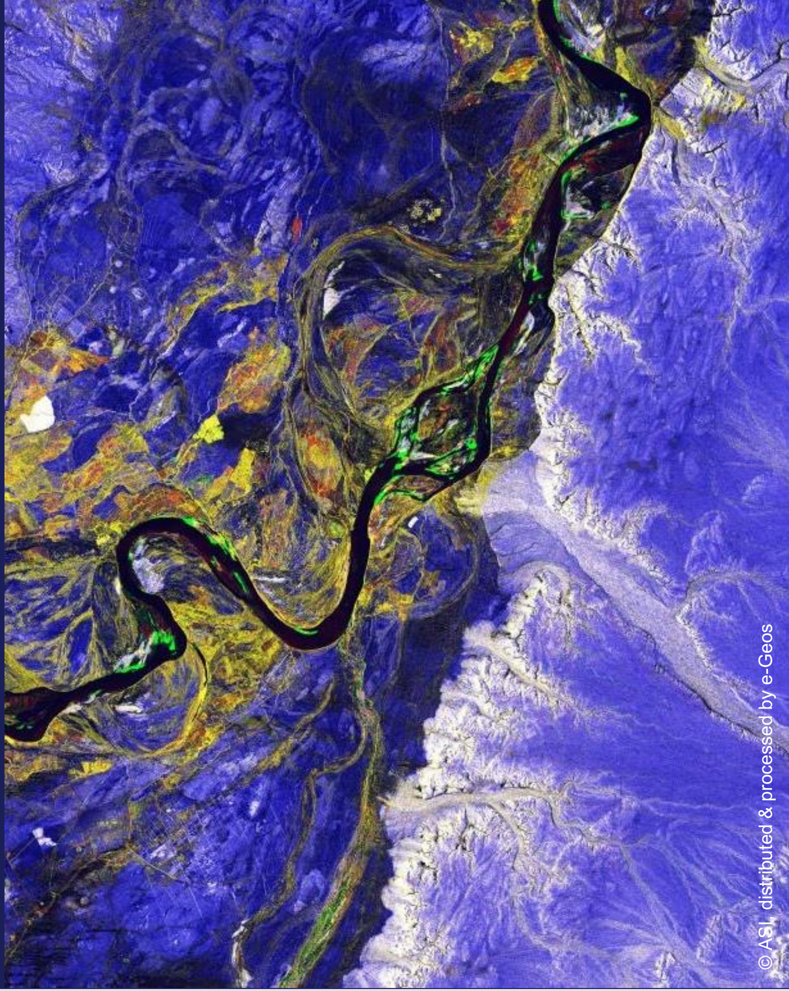
SPACE ALLIANCE

Thales Alenia Space teams up with Telespazio to offer a unique combination of expertise covering the entire value chain

System & Services



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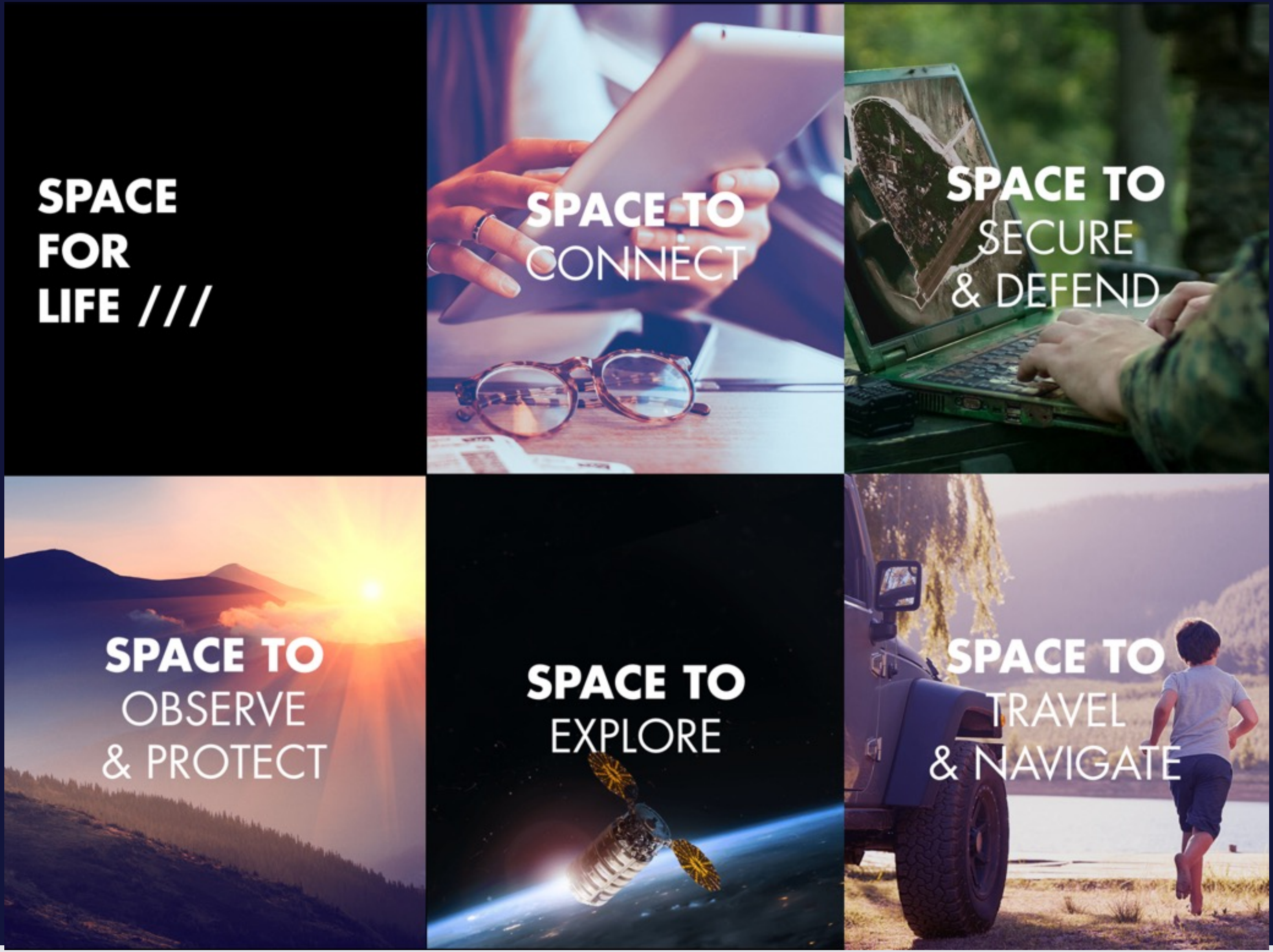
SPACE FOR LIFE ///
SPACE TO CONNECT
SPACE TO SECURE & DEFEND
SPACE TO OBSERVE & PROTECT
SPACE TO EXPLORE
SPACE TO TRAVEL & NAVIGATE


FROM EARTH TO DEEP SPACE...
36 000 KM
23 000 KM
8 000 KM
800 KM
700 KM
400 KM

THALES ALENIA SPACE ITALY - ROME

///Competencies

- Satellite assembly integration testing
- Space systems design
- Earth observation radar
- Navigation
- Telecoms Defence Satellites
- Antennas
- Equipment

4000 sqm

clean rooms

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DONI MISSION

/// DESIGN, MANIFACTURE AND SUPPLY END-TO-END SYSTEM FOR

SATELLITE OBSERVATION & NAVIGATION SOLUTIONS

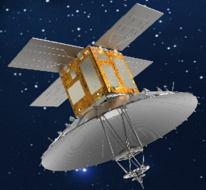
FROM EQUIPMENT TO END-TO END SYSTEM

COSMO-SkyMed

Copernicus

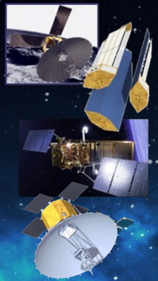
Galileo

EOS20



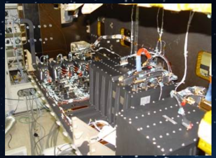
DONI Product Lines

Radar & EO MW systems and constellation



EO Radar

4 products covering almost all EO applications, from very high resolution (HP-R, HE-R) to high revisit acquisition scenarios (constellation HE-R, HR-R).



PDHT

State of art **P**ayload **D**ata **H**andling & **T**ransmission solutions to enable high data volume/rate provision.

Microsatellites & Constellations

Micro constellation solutions NiMBUS / PLATiNO multi-mission platform, to be used also for HR-R.

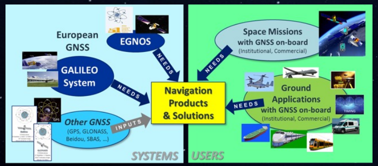
DONI Space Segments

PRISMA platform product family solutions & optical satellites

Ground Systems & E2E Solutions

Ground solutions encompassing product concept to enforce "bundle" concepts capabilities and small sat constellations management. Using Big data and deep learning technologies, with cybersecurity solutions

Navigation systems, payloads, satellites & Aerocom



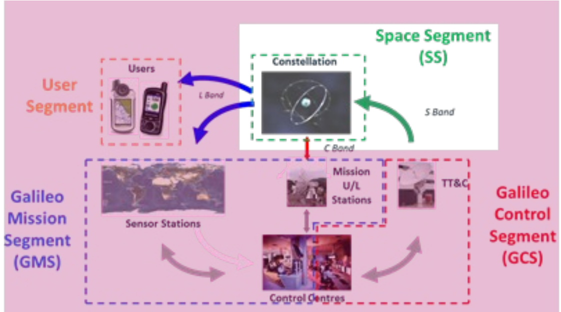
Navigation Users Solutions

Spaceborne and Ground navigation Solutions for specific user contexts (Space, SoL railway solutions, synchronets, navigation assisted solutions, Space & ground receivers)

Navigation & Aerocom Systems Solutions

System and Payload/Satellite Solutions for Air Traffic Management Safety of Life communications Integrated with GNSS Navigation Solutions.

NAVIGATION SATELLITES - GALILEO SPACE SEGMENT



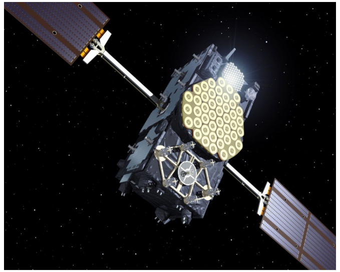
The Galileo Space Segment will comprise a constellation of a total of 30 Medium Earth Orbit (MEO) satellites, in a so-called Walker 24/3/1 constellation. The Galileo satellite constellation has been optimized to the following nominal constellation specifications:

- Circular orbits (satellite altitude of 23 222 km)
- Orbital inclination of 56°
- Three equally spaced orbital planes
- Eight operational satellites, equally spaced in each plane
- Constellation geometry repetition period of 10 sideral days (corresponding to 17 orbital revolutions)

IOV Phase

4 satellites In-Orbit

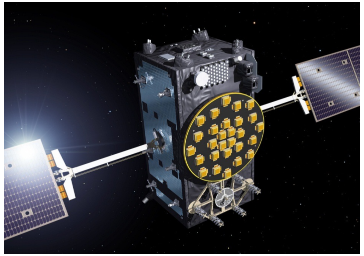
Mass at Launch	700kg
Power Consumption	1420W
Dimensions	2.7 x 1.6 x 14.5 m
Orbit Injection	Direct into MEO orbit
Attitude Profile	Yaw Steered



FOC Phase

24 satellites In-Orbit

Mass at Launch	733kg
Power Consumption	1900 W
Dimensions	2.5 x 1.1 x 14.7 m
Orbit Injection	Direct into MEO orbit
Attitude Profile	Yaw Steered



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NAVIGATION SATELLITES – GALILEO SECOND GENERATION

/// On-board Galileo 2nd Generation to boost performance and cybersecurity for the constellation

- Inter-satellite links
- Digitally configurable Antennas
- Full electric propulsion systems
- First satellites in orbit by 2024

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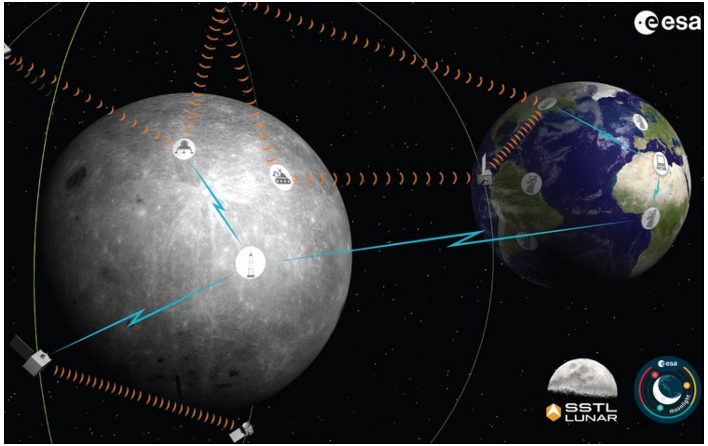
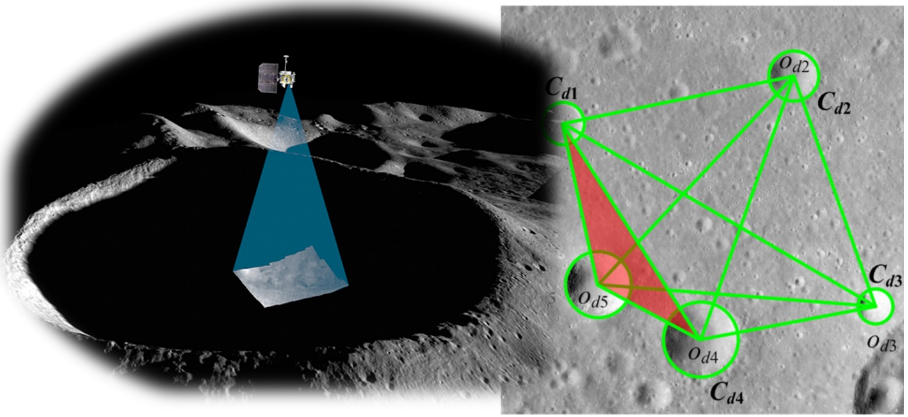
NAVIGATION SATELLITES – LUNAR NAVIGATION

/// Thales Alenia Space Has Been Selected By The European Space Agency To Study Specific Technical Aspects For A Future Lunar Radio Navigation System



- Real-time On-Board Navigation
- Earth Sciences
- Launch Vehicle Range Ops
- Attitude Determination
- Time Synchronization



R&D – Autonomous Orbit Determination With Crater Matching

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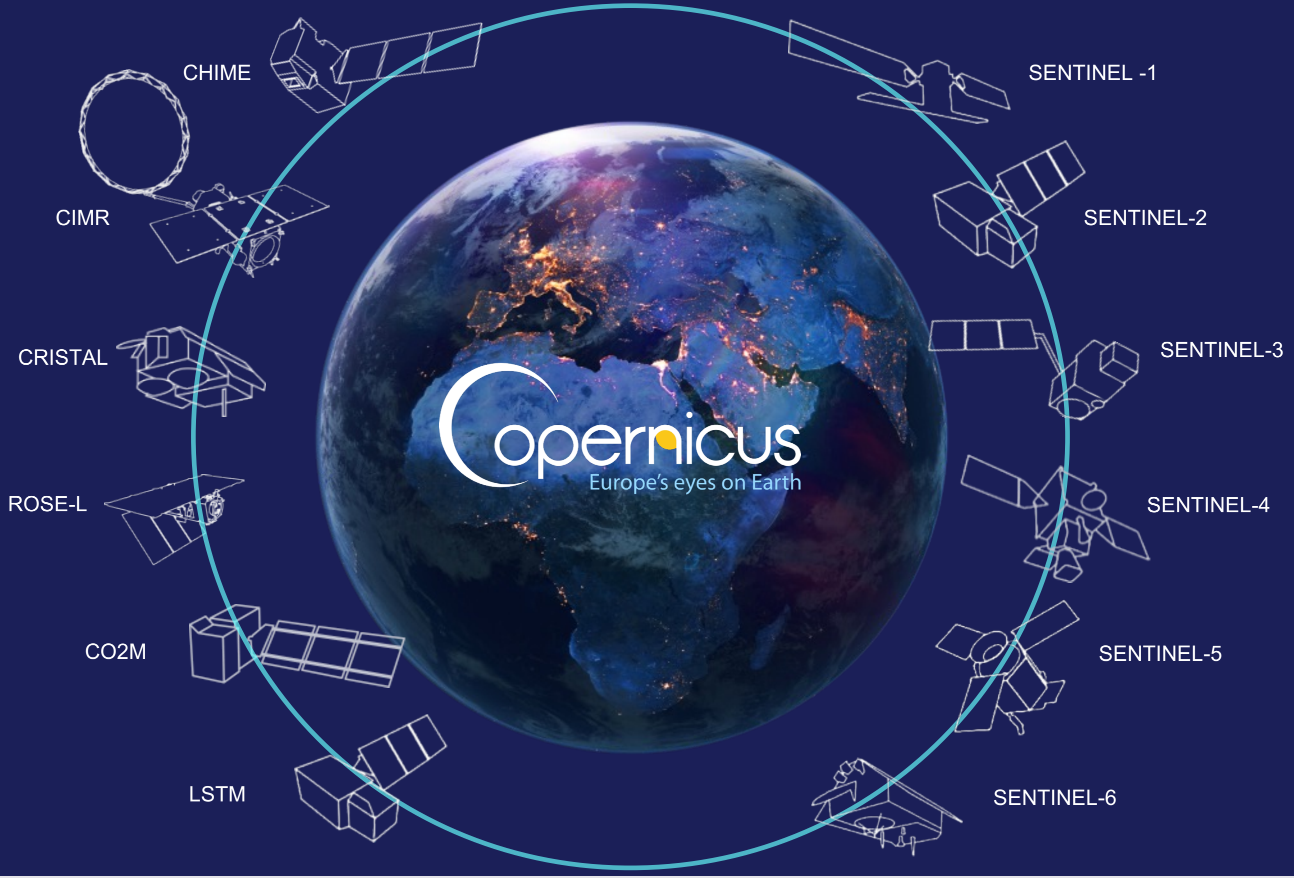
SPACE TO OBSERVE & PROTECT



LAND MONITORING

EMERGENCY MANAGEMENT

MARINE MONITORING

ATMOSPHERE MONITORING

CLIMATE CHANGE

SECURITY

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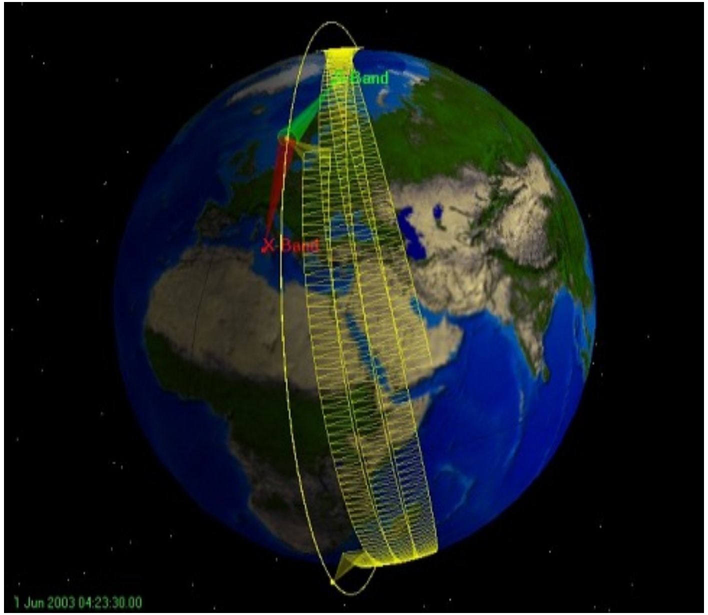
THE ITALIAN CHAMPION IN EO (1/2): COSMO-SKYMED

The **COSMO-SkyMed** (Constellation of small Satellites for the Mediterranean basin Observation) Series consists of two generations of Synthetic Aperture Radar (SAR) satellites with the overall objective of providing frequent all-weather Earth observation, which can be applied to defence and civil needs.

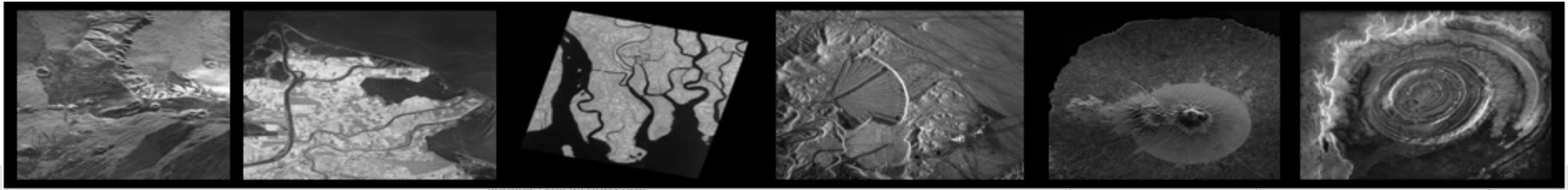


/// 4 satellites High resolution, X-Band,

/// > 2 x 650 km on ground access capability

/// Global Earth access (including polar caps) with all weather / night-daylight sensing capability

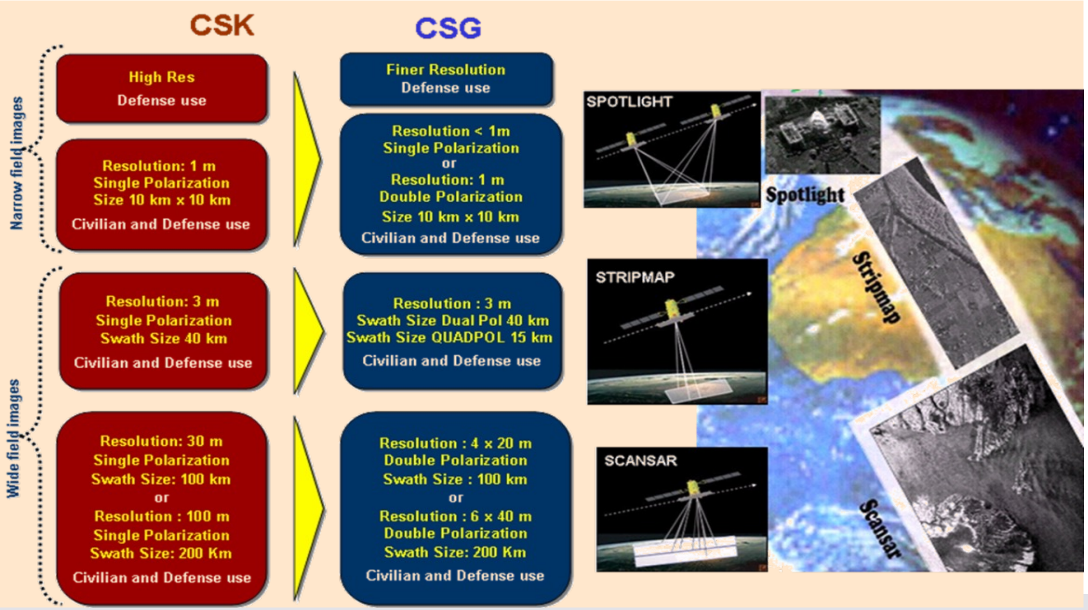
/// ***Conceived for dual use***: performance, accessibility, operational capability and security.

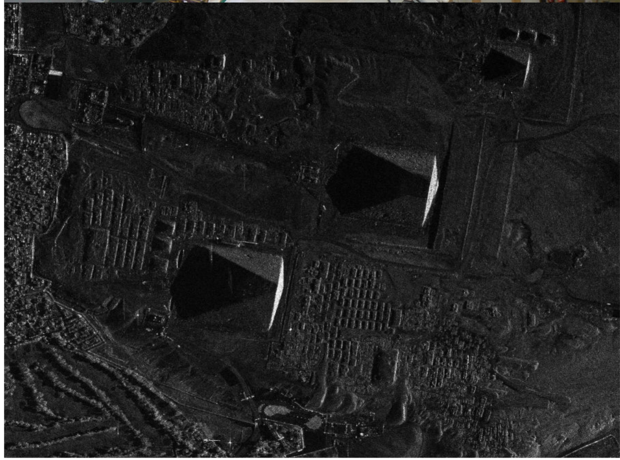


THE ITALIAN CHAMPION IN EO (2/2): COSMO-SKYMED & COSMO SG

COSMO-SkyMed Second Generation (CSG) consists of two enhanced SAR satellites. It provides Polarimetric SAR.

/// 2 satellites, Last launch on Jan 2022.





THE ADVANCED TECHNOLOGIES UNIT

TASI

Domain Telecommunication Italy (DTI)

Domain Observation and Navigation Italy (DONI)

Domain Exploration and Science Italy (DESI)

Research, Innovation Advanced and Constellation Projects

Advanced Projects & Technologies

Advanced Technologies

Focus ON

- /// Artificial Intelligence
- /// Quantum Technologies
- /// Cyber Security
- /// Virtual Reality, Augmented R. ,Mixed R.
- /// GNSS-Reflectometry
- /// Digital Twin

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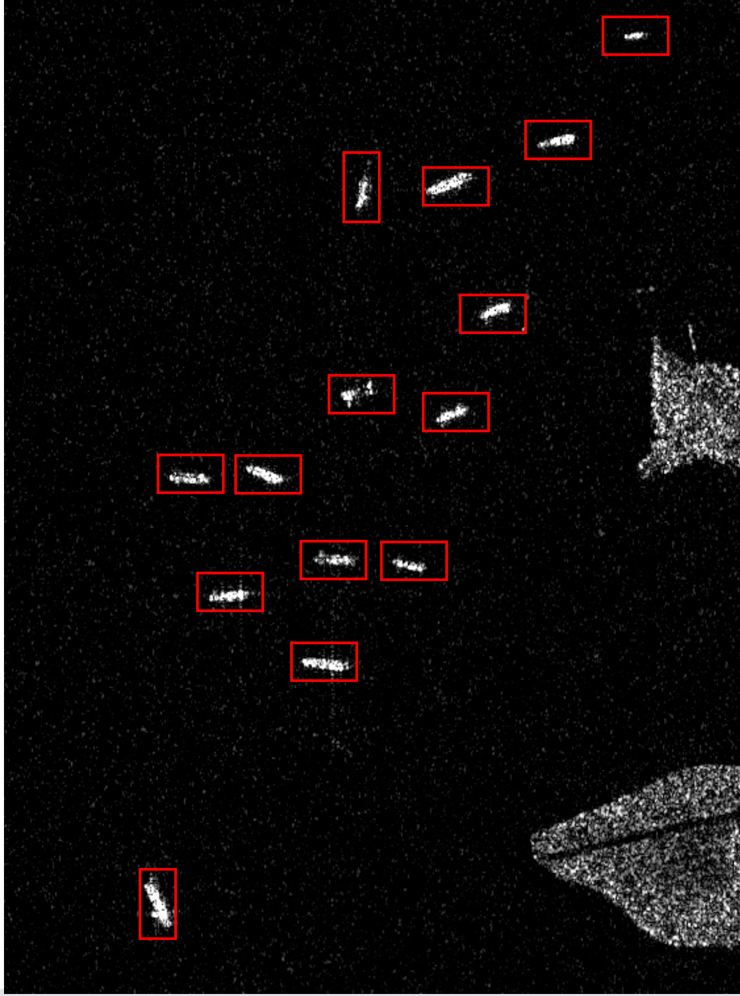
OUR INTERESTS IN HPC APPLICATIONS

/// Ground Applications

- Payload Data processing (oil spill detection, Vessel Detection, …)
- Mission Planning Optimization & Acquisition Scheduling
- Mission Analysis Optimization and Complex Orbital/Trajectory Simulation
- Critical Failure Prediction
- …

/// On-board applications

- Sub-system Failure detection and reaction
- Processing of SAR Raw data (on-board focusing)
- Cognitive radar (automatic detection of targets)
- Data compression
- Automated collision avoidance
- Security (anti-jamming, chiphering, …)
- Formation flying satellites
- Precise spacecraft attitude determination



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THE PROBLEM OF ON-BOARD COMPUTING

/// On-board payload data processing encompasses the data acquisition, transfer, storage, data compression or reduction and transmission to ground of instrument and sensor data. Quite often the amount of raw data generated by modern instruments is in excess of what can be transmitted to ground.

/// The issue for the space industry is that it is not possible to reuse in a straightforward way the hardware platforms of terrestrial applications, given the specific constraints of satellite data systems especially in terms of radiation.

GROUND SEGMENT

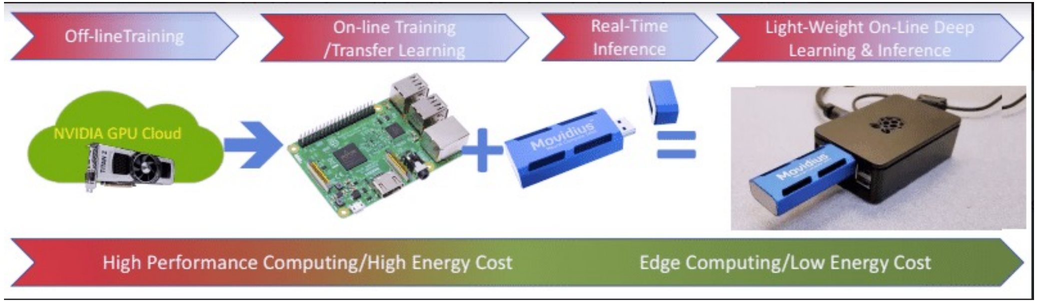
The Training stage defines the weights of each connection:

- Massive dataset
- High computational efforts

SPACE SEGMENT

The Inference stage uses only NN architecture with weights :

- Real time analysis
- Low computational efforts

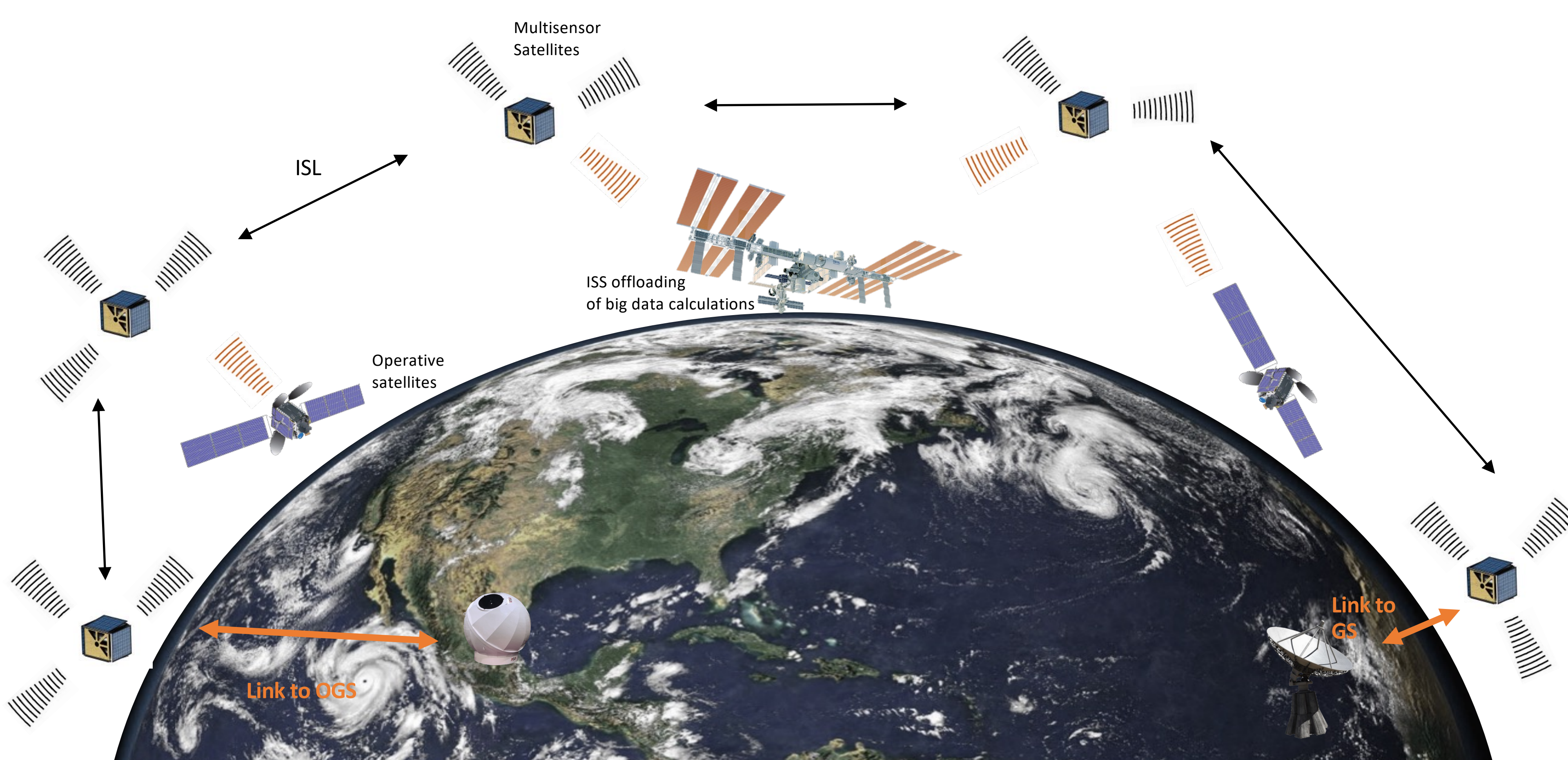


Strong Interest of TAS in testing novel computing paradigms to

- Increase Computational efficiency
- Reduce Power Consumption

Interest in photonic and quantum computing platforms

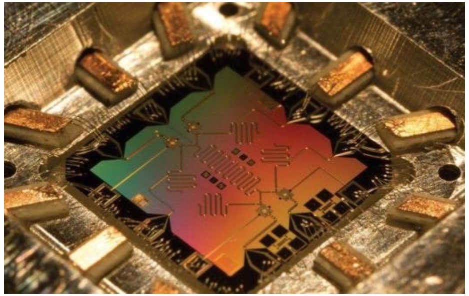
TREND ON DISTRIBUTED COMPUTING ON-BOARD SATELLITE



PART 2:
QUANTUM TECHNOLOGIES FOR SPACE

DONI'S INTEREST IN QUANTUM TECHNOLOGIES

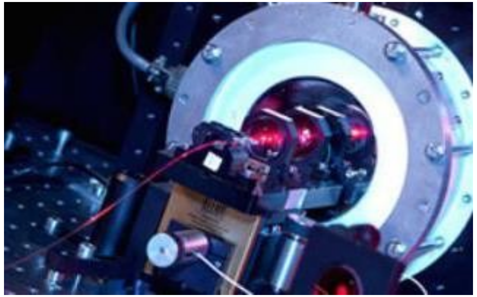
Empower Computing



/// **Goal:**

Enable New previously impossible applications enabled by Quantum Computing exploiting quantum systems' properties (superposition, entanglement)

Enable New Sensing

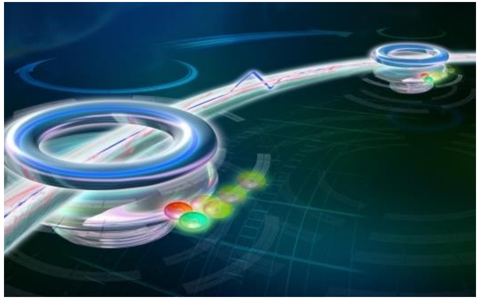


/// **Goal:**

Exploiting quantum systems to measure a physical quantity (classical or quantum)

- **Increase Sensitivity, resolution and quality of the measurements**
- **Overcome classical Measurement limits**

High Performance/Secure Communications



/// **Goal:**

Exploiting quantum systems to develop new ways for encoding and transmitting information over long distances

- **Upgrade existing critical communication infrastructures to prevent quantum attacks**
- **Exploit Distribution of Entangled state to implement protocol for new features**

Common Objectives for all topics of interest

- Identify advantages and drawbacks compared to classical solutions
- Space application sustainability (costs, operational and environmental)
- Identify expected time frame for use in IoD / Commercial missions
- Define a technology roadmap for space misisons
- Develop, at short term, solid demonstrator to show capability and space use feasibility

DONI APPLICATIONS OF QUANTUM TECH

TASI is putting in place a long term research and development programme on quantum technologies applied to space. In this frame, Domain Observation and Navigation Italy (DONI) sees potential Technologies in the three branches of QT:

/// QUANTUM SENSING

- Explore Performance, limitations and applicability for Quantum Navigation systems based on Quantum Accelerometer, Gyroscopes, Gravimeters, proposing novel schemes and implementing porotypes where possible
- Quantum Illuminations techniques analysis, including FSO feasibility and performance analysis with Channel Impairments simulations and device prototyping
- RF Signal Generation and Manipulation via Integrated photonic circuits

/// QUANTUM COMPUTING

- Quantum computation architecture and processing models case studies targeting on-board satellite QC. (LOQC, Boson Sampling, Superconductive,…)
- Identify and Engineer Quantum Algorithms assuming NISQ computational capability, impacting the Satellite Communication/Navigation/Observation

/// QUANTUM COMMUNICATION & TIME METROLOGY

- Quantum protocols adaptation for secure Time-Frequency satellite transfer
- End-to-end QKD protocols, architecture and components vulnerability analysis taking also into account trusted nodes
- Quantum & Photonic Clocks benchmarking and study

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DONI APPLICATIONS OF QUANTUM TECH

MACRO-AREA	SPECIFIC AREA	DESCRIPTION	TIME PERIOD	TARGET USE CASES
QUANTUM COMMUNICATION & TIME METROLOGY	Unconditionally Secure Information Transfer	Exploring new solutions enabled by hybrid QKD systems (fiber and free space) together with the concept of &Trusted nodes	Near term (< 5 y.)	• Galileo Time Generation, Encryption and Trasnfer • Satellite autonomousnes enanchment due to highly stable clocks (Lunar environments or beyond) • Scientifc EO payload (e.g. gravitational wave detection)
	New systems for time\frequency generation and distribution	Photonic quantum Clocks for ground and space segment	Middle term (5÷10 y.)	
		QKD based optical Time Transfer in FSO	Middle term (5÷10 y.)	
QUANTUM COMPUTING	Enabling HPC both in space and on ground exploting hybrid Quantum\Classical computing to speed up space related complex tasks.	Testing and benchmarking photonic processors as hardware accelerator both onboard and at ground	Near term (< 5 y.)	• Enabling on-board Satellite computing with resilience to cosmic rays and van allen belt. • Integrated, efficient (space and energy consumption) computing platform
		Study, implementation and benchmarking of potentials Quantum Algorithms for space related tasks, considering all possible platforms (Ion, Cold Atom, Superconducting, photons)	Long term (> 10 y.)	• Constellations for Distributed computing in space • New platforms for efficient ground and on-board computing • Solving complex optimizazion problem like mission planning
		Photonic quantum machine learning and modular (NISQ) photonic machines	Middle term (5÷10 y.)	
QUANTUM SENSING	Quantum Sensing devices	Study, characterization and Space qualification of quantum platforms for sensing (superconductors, diamond vacancies, cold atom interferometers, photons)	Near term (< 5 y.)	• New generation quantum payload to enhance sensing capabilities for navigation, EO and SSA. (Augmented Orbit Determination systems, Magnetic/gravimetric field Mappings) • Augmenting capabilities of EO imaging systems with quantum physics (Entangle-Enanched SAR, LIDAR)
		Testing and benchmarking quantum devices as quantum gravimeters, magnetometers, gyroscopes, accelerometers, antennas	Middle term (5÷10 y.)	
	Augmentation of EO systems	Testing Microwave Photonics for RF Signal Manipulation (in SAR Satellite systems)	Middle term (5÷10 y.)	
		Evaluating new system for EO augmentation based on Quantum Mechanics: Quantum Illumination, Radar, Ghost Imaging	Long term (> 10 y.)	

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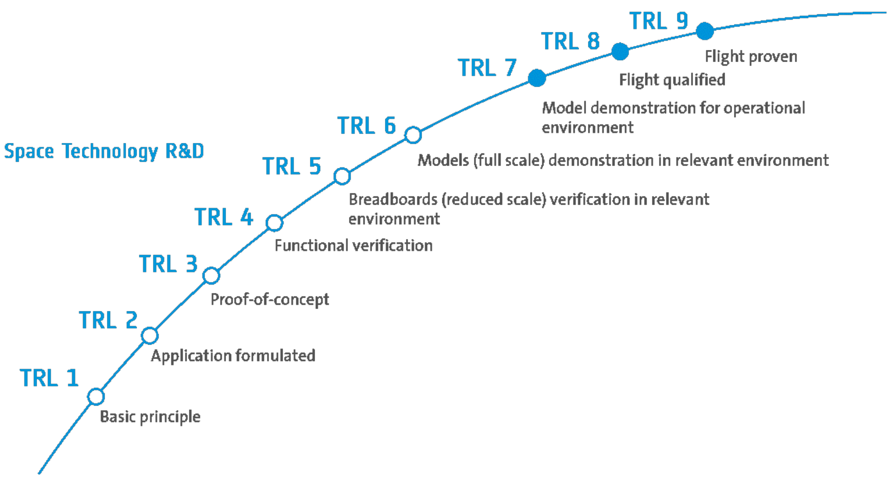
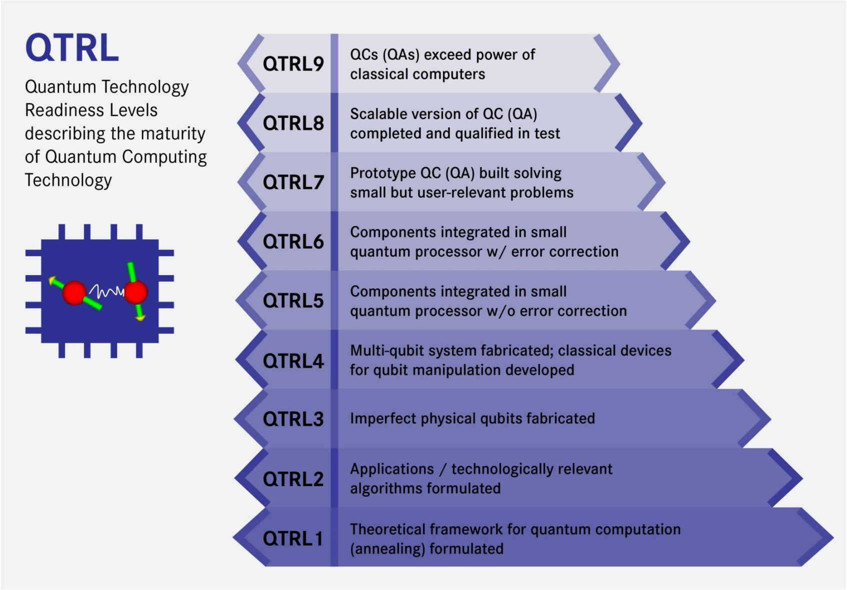
TECHNOLOGY READINESS LEVEL

ESA TRL For Space Technologies



Quantum TRL



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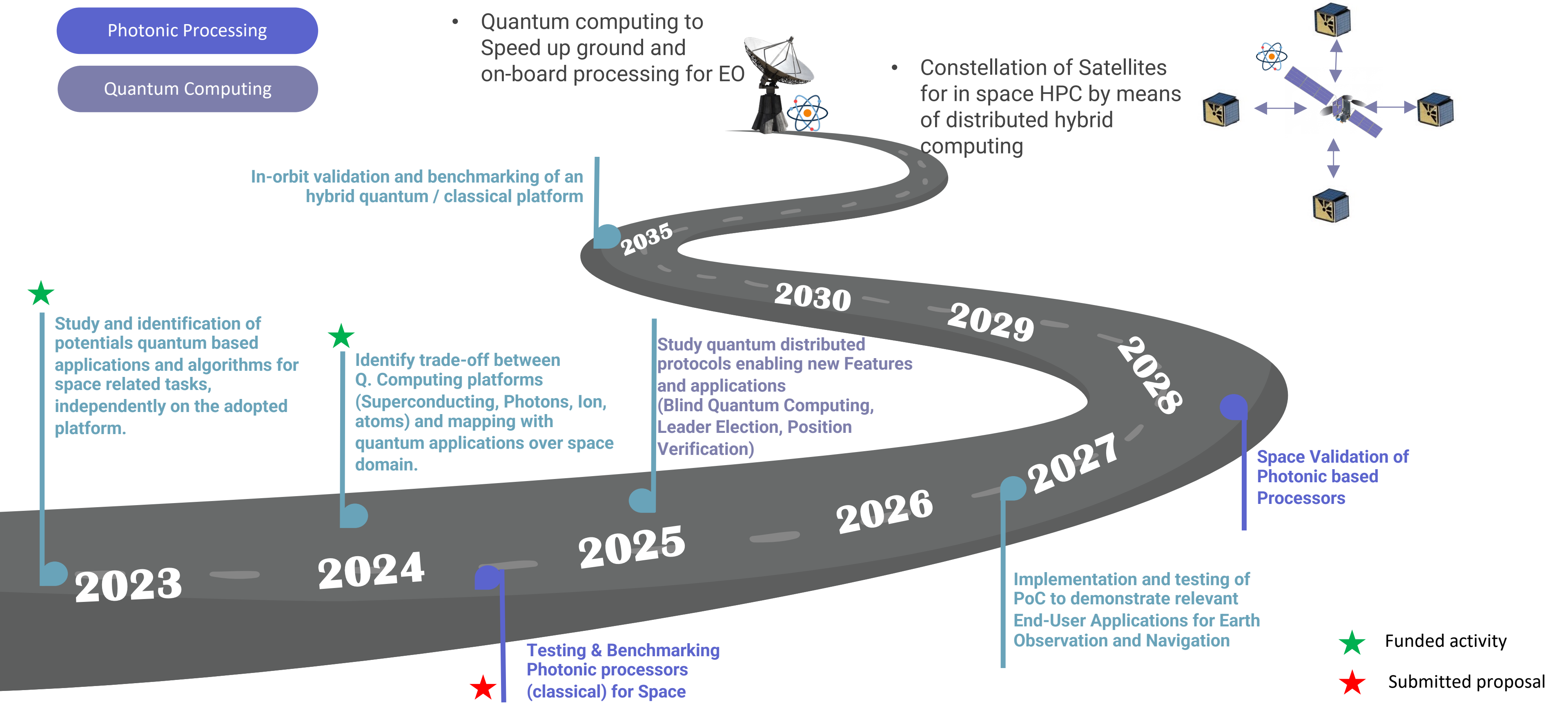
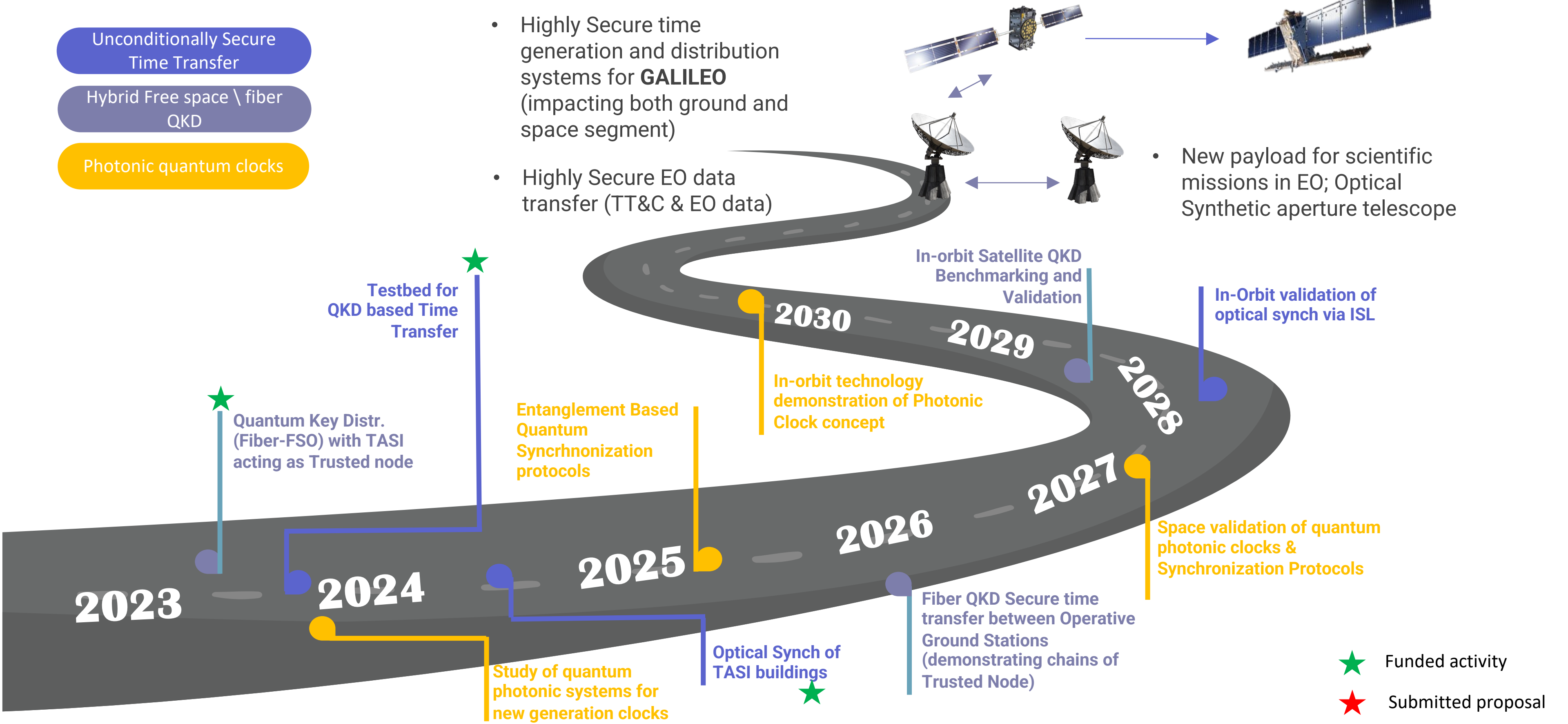
https://www.fz-juelich.de/en/ias/jsc/about-us/qip/technology-readiness-level-of-quantum-computing-technology-qtrl?expand=translations,fzjsettings,nearest-institut

PART 3:
TASI ROADMAPS FOR QUANTUM TECH

ROADMAP 2/3: HYBRID QUANTUM \ CLASSICAL COMPUTING



ROADMAP 1/3:QUANTUM COMM. & TIME METROLOGY



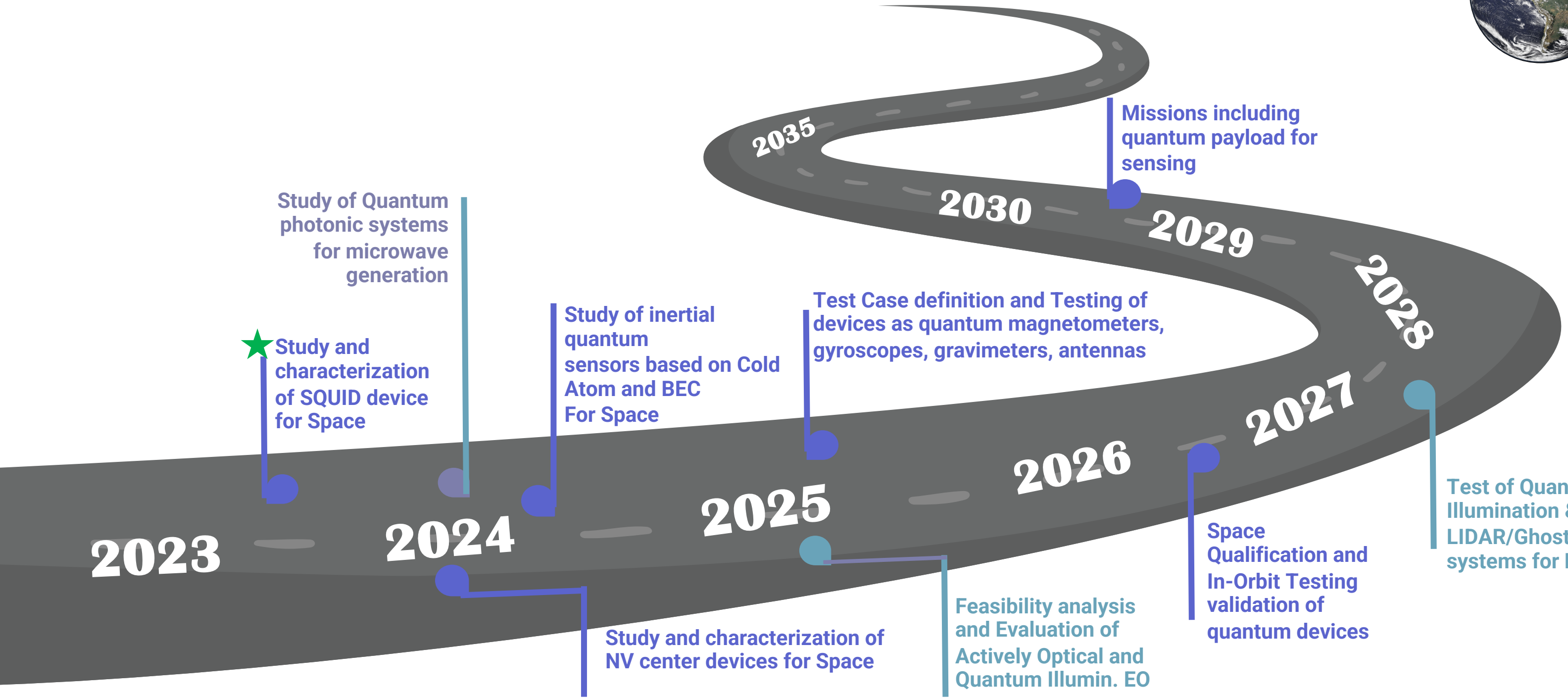
ROADMAP 2/3: QUANTUM SENSING

Quantum devices

Quantum augmentation of EO systems

- New EO imaging Systems augmented with quantum capabilities (**Cosmo SKyMed**, **Sentinel**)

- New generation quantum payload to enhance sensing capabilities for Navigation, EO and SSA



Missions including quantum payload for sensing

Study of Quantum photonic systems for microwave generation

★ Study and characterization of SQUID device for Space

Study of inertial quantum sensors based on Cold Atom and BEC For Space

Test Case definition and Testing of devices as quantum magnetometers, gyroscopes, gravimeters, antennas

Test of Quantum Illumination & LIDAR/Ghost Imaging systems for EO

Space Qualification and In-Orbit Testing validation of quantum devices

Feasibility analysis and Evaluation of Actively Optical and Quantum Illumin. EO

Study and characterization of NV center devices for Space

★ Funded activity

★ Submitted proposal

ThalesAlenia Space
a Thales / Leonardo company

PART 4:
WHAT WE ARE DOING

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PASQUANS2: PROGRAMMABLE ATOMIC LARGE-SCALE QUANTUM SIMULATION

Objective: Develop next-generation programmable, large-scale atomic quantum simulators operating with up to 10000 atoms

Austria
- Alpine Quantum Technologies GmbH
- Österreichische Akademie der Wissenschaften
- Parity Quantum Computing GmbH
- Universität Innsbruck

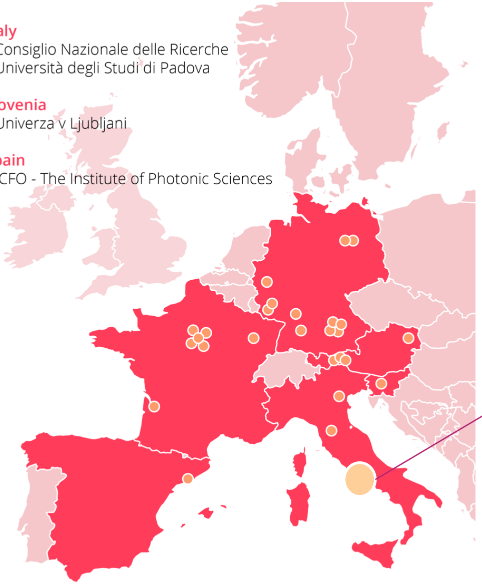
France
- Atos BULL
- Azurlight Systems
- Centre National de la Recherche Scientifique
- Electricité de France
- Institut d´Optique Théorique et Appliquée
- Exail
- PASQAL

Germany
- Eberhard-Karls-Universität Tübingen
- EURICE – European Research and Project Office GmbH
- Forschungszentrum Jülich GmbH
- Freie Universität Berlin
- Ludwig-Maximilians-Universität München
- Max-Planck-Institut für Quantenoptik
- Menlo Systems GmbH
- Qruise GmbH
- Ruprecht-Karls-Universität Heidelberg
- TOPTICA Photonics AG

Italy
- Consiglio Nazionale delle Ricerche
- Università degli Studi di Padova

Slovenia
- Univerza v Ljubljani

Spain
- ICFO - The Institute of Photonic Sciences



TASI role: End user

Develop one (or more) representative case studies to take advantage of several different computational paradigms and computational platforms (NISQ, real and emulated quantum computers)

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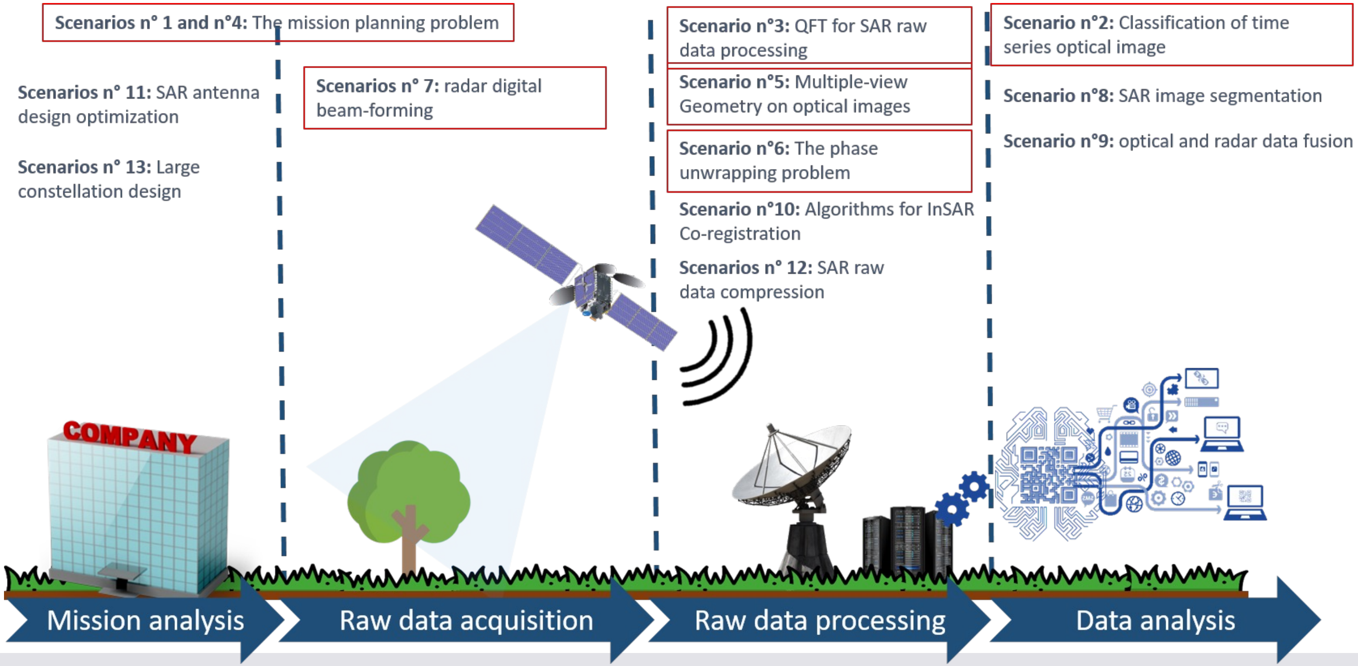
QC4EO – QUANTUM COMPUTING FOR EARTH OBSERVATION

Objective: identification of interesting quantum computing use cases for space (within next 15 years) and roadmap definition



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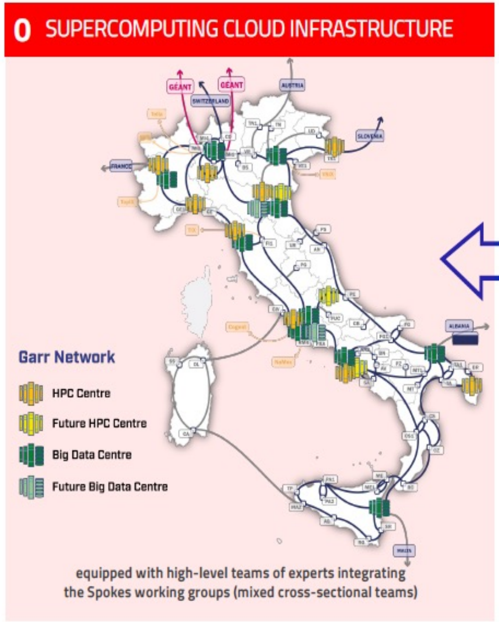
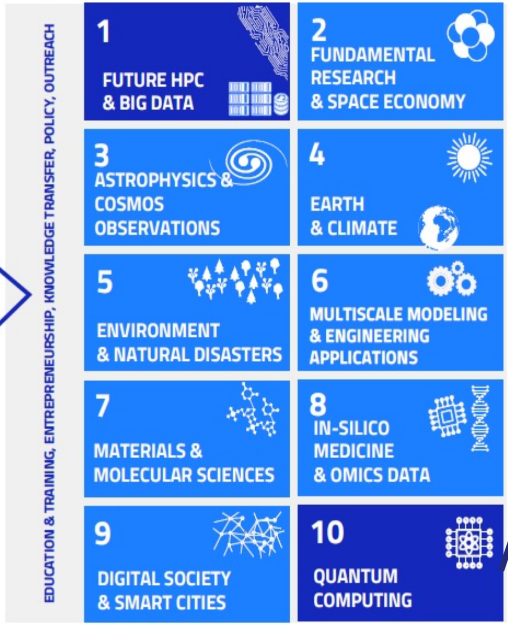
NATIONAL RESEARCH CENTER ON HPC, BIG DATA AND QUANTUM COMPUTING

ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

Objective: build a world-class supercomputing cloud infrastructure to store, manage and process all the produced data. Set up strong links between Academia, Industry



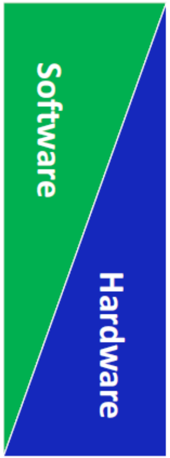


Spoke 10

WP1. Software
- Layer 1. Applications
- Layer 2. Algorithms

WP2. Middleware
- Layer 3. Emulation
- Layer 4. Compilation

WP3. Hardware
- Layer 5. Firmware
- Layer 6. Hardware



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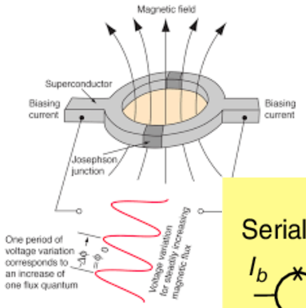
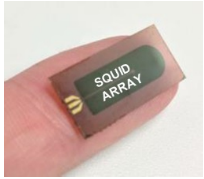
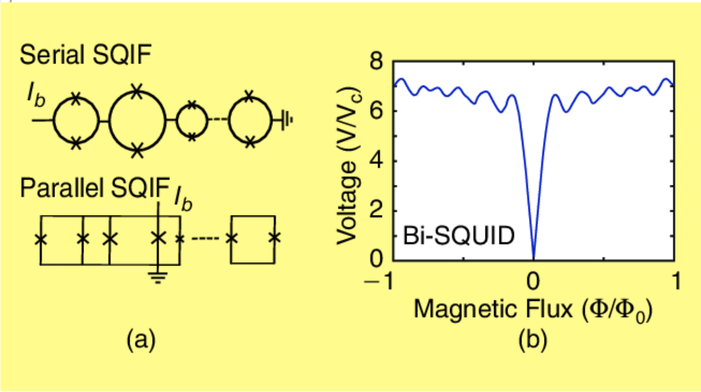
QU-PILOT

Objective: develop and provide access to the first, federated European fabrication (production) capabilities for quantum technologies. Provide experimental production capabilities for quantum technologies on the superconducting, photonics, semiconducting and diamond platforms, which will find application in computing, communication and sensing







TASI role: end user, benchmarking. Develop a highly sensitive superconducting magnetometer for space applications

FONDAZIONE BRUNO KESSLER

Quantum Antenna or Magnetometer

1. Wideband sensor
2. Sensitive to the magnetic component of EM waves
3. Determination of the direction of arrival

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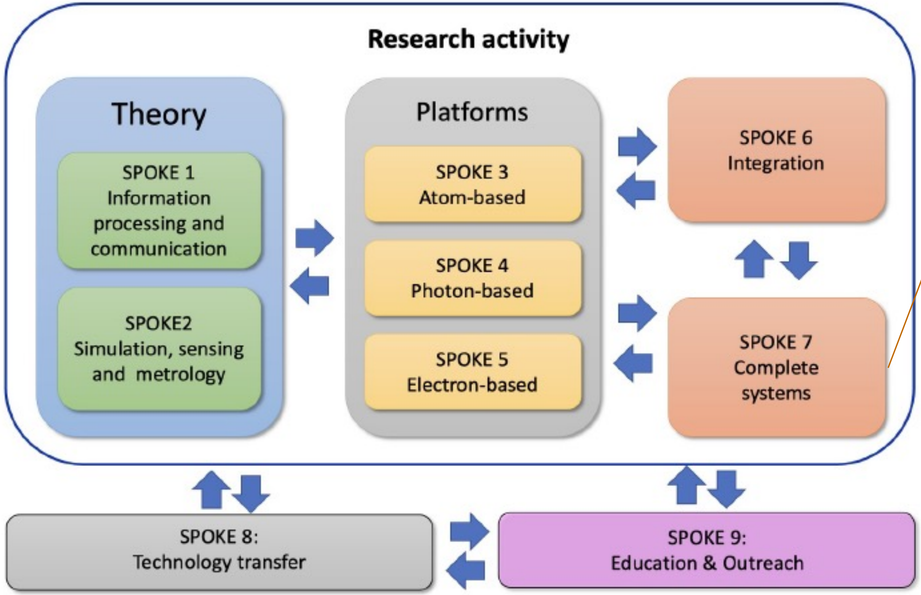
a Thales / Leonardo company

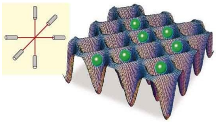
NATIONAL QUANTUM SCIENCE AND TECHNOLOGY INSTITUTE

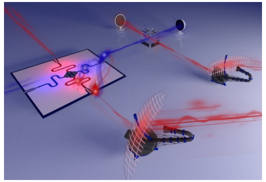
Objective: strengthening and coordinating the low-TRL research up to its translation into prototypes, favoring interfacing with industrial needs thanks to outreach and continued-education programs.



TASI is part of the Spoke 7, being interested in:

- Quantum devices for sensing (magnetometer)
- Quantum illumination
- QKD





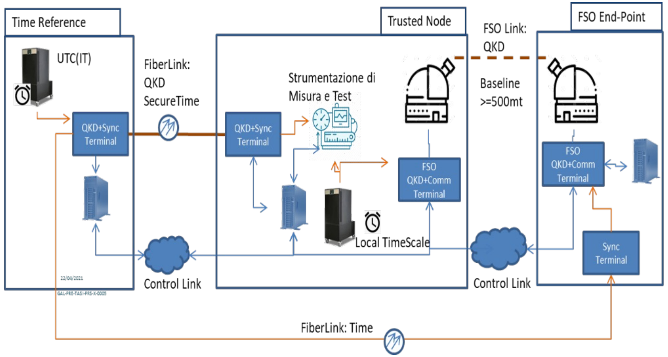
[Lanzagorta, Marco, and Jeffrey Uhlmann. "Space-based quantum sensing for low-power detection of small targets." Radar Sensor Technology XIX; and Active and Passive Signatures VI. Vol. 9461. International Society for Optics and Photonics, 2015

CYBER 4.0 - QUANTUM COMMUNICATION AND SYNCHRONIZATION TESTBED

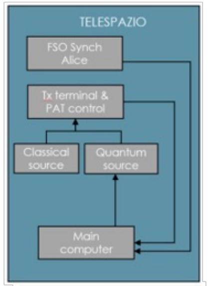
CYBER 4.0
CYBERSECURITY
COMPETENCE
CENTER

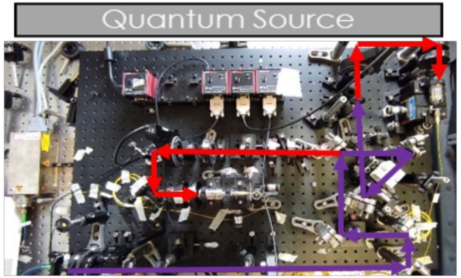
Objective: to industrially evaluate and demonstrate a set of enabling technologies in the field of Satellite based network security. More specifically:

- **Satellite FSO QKD**
- **Hybrid Fiber & FSO QKD**
- **Unconditional Cyphering** of a **Timing Distribution** signal
- **Trusted node over Satellite assets**

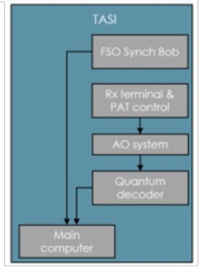


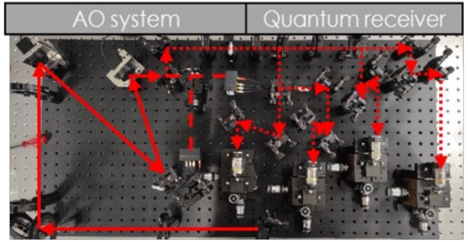
FSO TRANSMITTER – Telespazio





FSO RECEIVER - TASI





PRIME	PARTNERS		SUPPLIERS		
ThalesAlenia Space – DTI + DONI	TELESPAZIO una società LEONARDO e THALES	MPD	SAPIENZA Università di Roma	INRiM	CYBER 4.0 Cybersecurity Competence Center

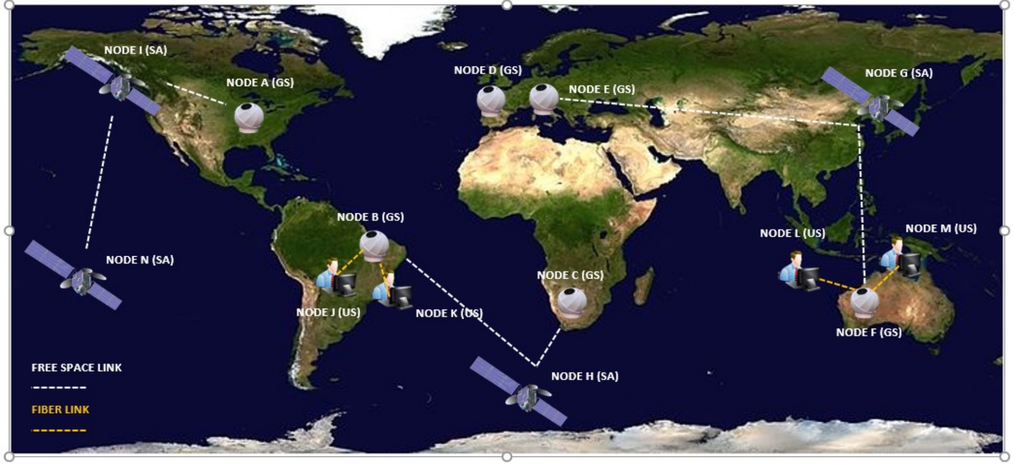
ThalesAlenia a Thales / Leonardo company Space

CYBER 4.0 – QKD SYSTEM VOLUME SIMULATOR

CYBER 4.0
CYBERSECURITY COMPETENCE CENTER

Objective: to develop a simulator of QKD constellations for secret key distribution

NETWORK



PRIME	PARTNERS				SUPPLIERS	
ThinkQUANTUM	ThalesAlenia Space (a Thales / Leonardo company) DTI +DONI	TELESPAZIO (una società LEONARDO e THALES)	OFFICINA STELLARE (OUR WORLD, YOUR SPACE)	Enginium	Università degli Studi di Padova	CYBER 4.0 CYBERSECURITY COMPETENCE CENTER

- **HW resources** optimization (number of satellites, size of ground and space optical terminals, …)
- **Costs** optimization
- **Performance** evaluation of different scenarios
- **Risk** analysis;
- Realization of a **digital twin** of the system.

ThalesAlenia Space (a Thales / Leonardo company)

PART 5:
QUANTUM COMPUTING USE CASES

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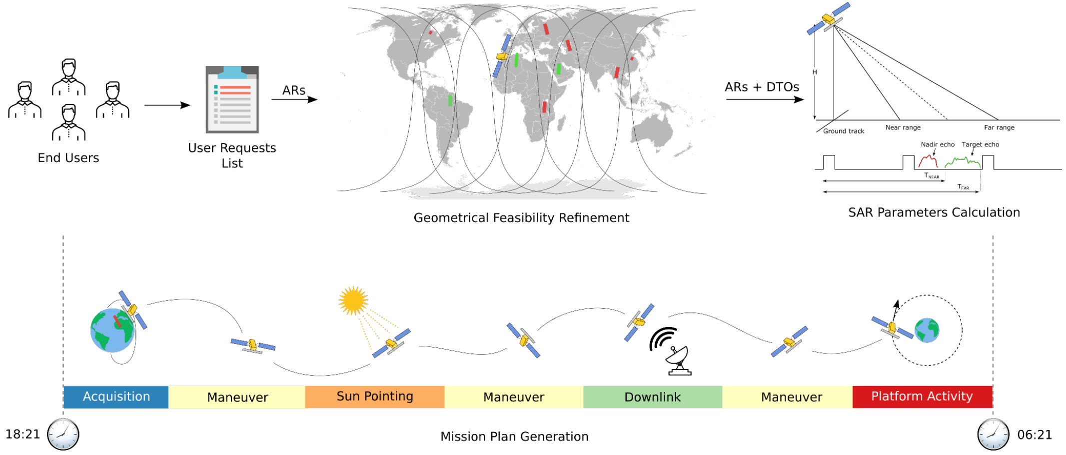
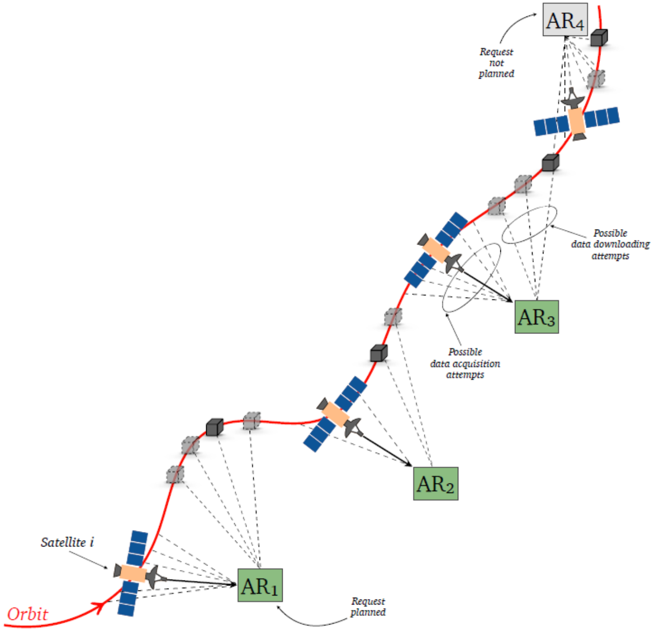
THE MISSION PLANNING PROBLEM (1/2)

Optimal scheduling of satellite observations for a given list of user requests (Knapsack problem)



$2^{(N*M*\vartheta)}$ possible solutions

N is the number of satellites ~ 100
M the number of AR for each satellite ~ 1000
ϑ the number of DTO for each pair of satellite-AR ~ 10



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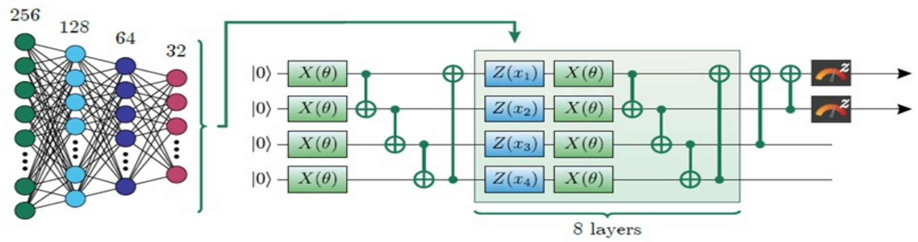
THE MISSION PLANNING PROBLEM (2/2)

Full quantum solution

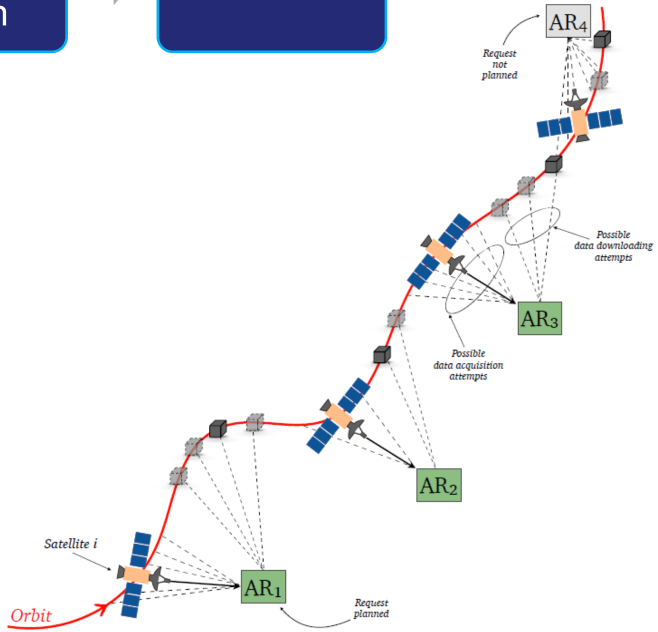
EO problem → QUBO formulation → Ising mapping → Ground state search → Read-out

Stollenwerk, Tobias, et al. "Image Acquisition Planning for Earth Observation Satellites with a Quantum Annealer." arXiv preprint arXiv:2006.09724 (2020).

Hybrid approach



Rainjonneau, Serge, et al. "Quantum algorithms applied to satellite mission planning for Earth observation." *arXiv preprint arXiv:2302.07181* (2023).



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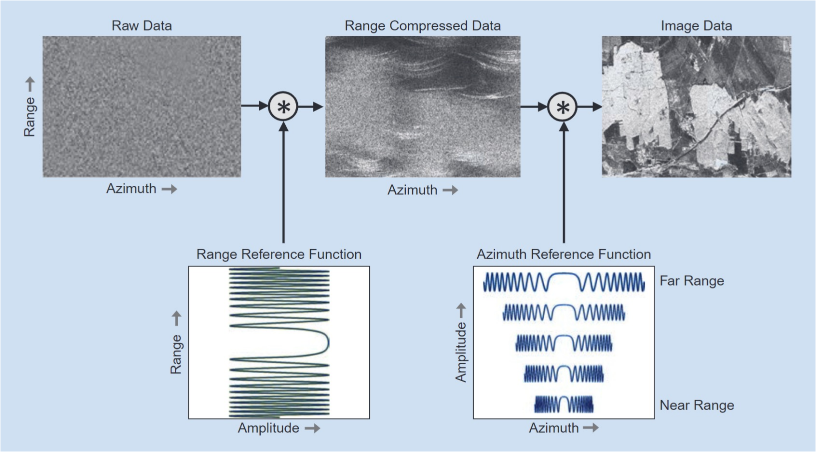
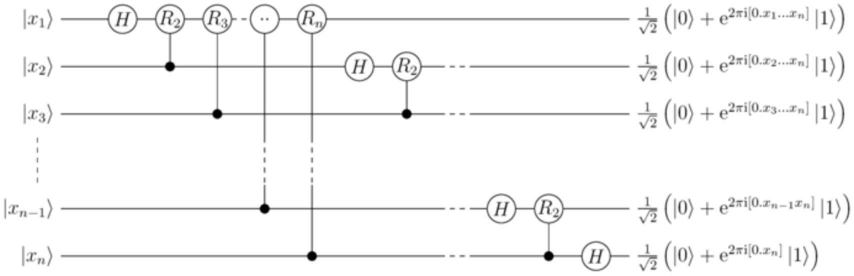
SAR RAW DATA PROCESSING

SAR raw data are processed on ground because of the huge computational power needed. Main bottlenecks is the number of FFT \ IFFT needed to focus a SAR image





QFT does not offer a direct quantum speedup compared to FFT. However, a speedup can be achieved by incorporating multiple classical processing steps in a more complex quantum circuit and exploiting the quantum representation of data.

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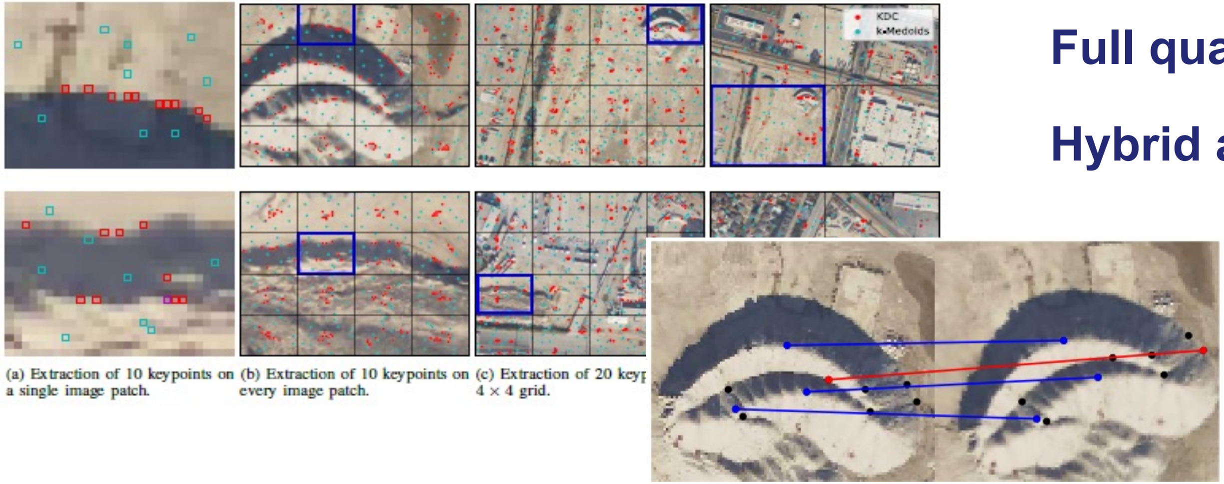
MULTIPLE-VIEW GEOMETRY ON OPTICAL IMAGES

Alignment of multiple images of a given area of interest to analyse the changes that have occurred on the area of interest as time has passed and perform terrain reconstruction. This problem can be tackled with bundle adjustment, which consists in estimating the different changes by minimizing the re-projection error.



Full quantum solution → QUBO

Hybrid approach → QML

Piatkowski, Nico, et al. "Towards Bundle Adjustment for Satellite Imaging via Quantum Machine Learning." *2022 25th International Conference on Information Fusion (FUSION)*. IEEE, 2022.

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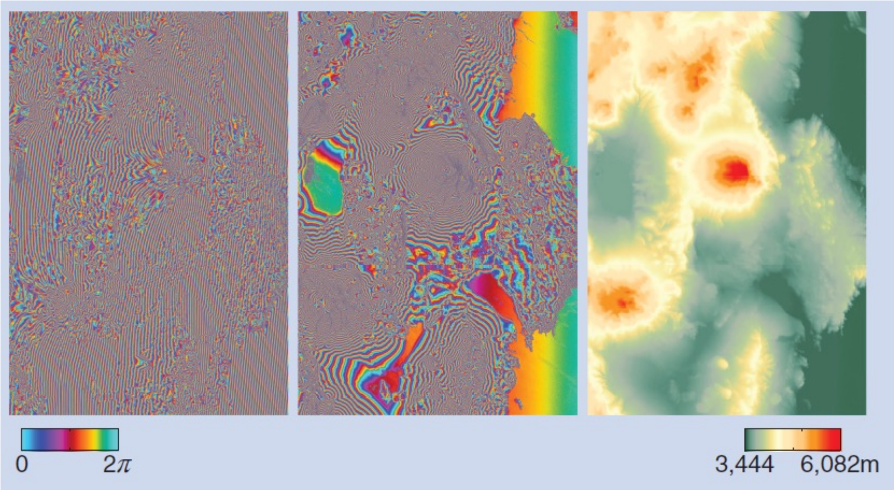
THE PHASE UNWRAPPING PROBLEM

recovering unambiguous phase values from a two-dimensional array of phase values known only modulo 2π rad

$$\phi_i = \varphi_i + 2\pi k_i$$

$$E = \sum_{(s,t)\in A} W_{st}\left(k_t - k_s - a_{st}\right)^2 + \sum_{s\in A} \omega_s\left(k_s - a_s\right)^2$$



find the best array ok k (one k value for each pixel in the InSAR image) that minimizes the energy cost function E

Full quantum solution → QUBO

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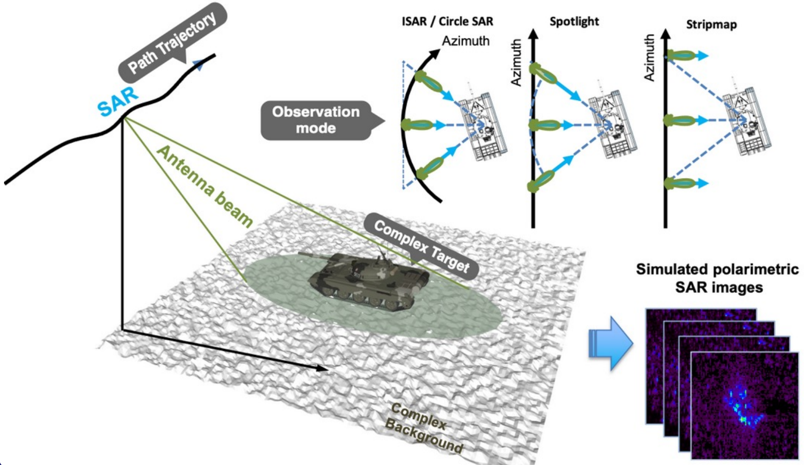
QUANTUM COMPUTING FOR EM SIMULATION (1/2)

Simulate the EM response of a complex-shaped target for SAR

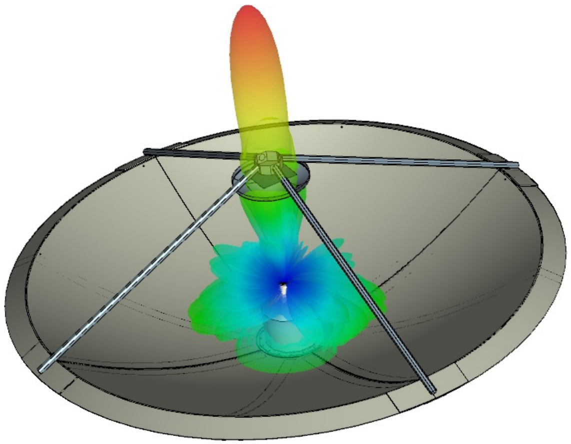
- Improving target detection
- Improving system calibration with non-conventional target



Chiang, Cheng-Yen, et al. "SAR Image Simulation of Complex Target including Multiple Scattering." *Remote Sensing* 13.23 (2021): 4854.

Antenna design optimization

- Improving overall performances of SAR systems
- Improving beamforming



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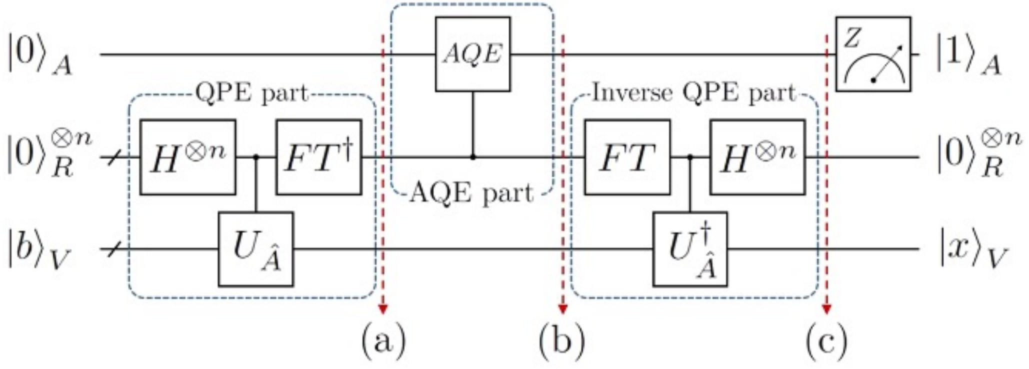
QUANTUM COMPUTING FOR EM SIMULATION (2/2)

/// Cast the problem into the solution of a linear system of equations:

- Help in solving PDEs based on **FEM techniques**
- Based on **HHL algorithm**
- It has been proven that calculation of EM scattering cross section of an arbitrary target is exponentially faster than the best classical algorithm



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PART 6: CONCLUSIONS

Is Space ready for the Quantum Leap?

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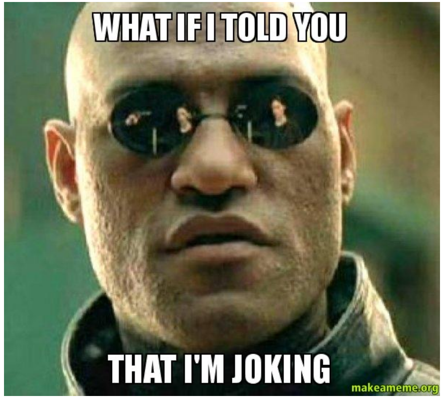
Is Space ready for the Quantum Leap?

NO

Is Space ready for the Quantum Leap?

NOT ENTIRELY ~~NO~~



…but we are working for turning this answer into "yes" within next few years

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Is Space ready for the Quantum Leap?

/// **Quantum tech** is a huge word encompassing a large area of applications and not all of these share the same maturity

/// Quantum **communication** is ready for the market with several industrial applications, while quantum **sensing** is approaching this status with high value demonstrations

/// Quantum **computing** is still in its infancy, in particoular when applied to space systems. However, interesting applications are emerging also in space area and these could be potential breakthrough

/// There is a growing global **trend** of investing resources in quantum applications for space. Europe and our company are stronly involved in this trend

/// Space companies are looking to make their systems as independent as possible and to move computation in orbit. **Hybrid model** that combines classical HPC tasks with quantum properties could be the winning solution

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ARE YOU READY FOR THE QUANTUM LEAP?

///Do you want to contribute to develop new technologies for space?

///Join us at Thales Alenia Space in Italy, where we have a lot of opportunities for students and seniors:

- Staff position within out team in Rome
- Industrial PhD
- Thesis
- Stages

///Don’t hesitate to get in touch with us for further information

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THANKS FOR YOUR ATTENTION

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