#INNOVATION@DET

Opportunità di collaborazione con DET in ambito spazio

F. Dovis

Politecnico di Torino

1859

DET is space

Il dipartimento di Elettronica e Telecomunicazioni è parte attiva in diverse iniziative di ampio respiro che prevedono trasferimento tecnologico verso le aziende e il mondo industriale

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA | NODES Nord Ovest Digitale E Sostenibile

PNRR Ecosistemi dell'innovazione

Nord Ovest Digitale e Sostenibile - NODES

NODES is an Innovation Ecosystem involving territories in Piemonte, Valle D'Aosta and the bordering provinces of Lombardia (Pavia, Como and Varese), represented by its innovation actors (universities, innovation clusters, research centers, competence centers, incubators and accelerators) and linked to the productive and research vocations that represent the excellence of the territories. NODES is organized into 7 spokes, each characterized by a specific focus under the umbrella of the **digital and ecological transitions**

https://www.ecs-nodes.eu/

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA | NODES Nord Ovest Digitale E Sostenibile

Space4You SPace Activities and CompEtences for industrY bOost in bUsiness

OBJECTIVES

- Supporting technology transfer and access to academic capabilities by developing a **Distributed Lab** and a related **knowledge portal**.
- Conducting applied research on both **upstream and downstream areas** with a focus on on innovative technologies related to miniaturised spacecrafts.
- Supporting the development of **innovative services and business model** related to New Space Economy paradigms.

- **Set-up of a distributed lab, networking facilities already available and developing new ones**
- **Implementation of 'The Knowledge Portal,' an accessible database of competencies and skills available in the research aerospace ecosystem**

Flagship Scientific Coordinator

prof. Sabrina Corpino, Politecnico di Torino
prof. Fabio Dovis, Politecnico di Torino

PNRR Partenariato Esteso Aerospazio – Space It Up!

OSSERVAZIONE DELLA TERRA

1. SISTEMI SATELLITARI

2. SYSTEM ENGINEERING & DIGITAL TWIN

3. REMOTE IMAGING SENSING (MICROWAVE/ OPTICAL)

4. REMOTE NON-IMAGING / HIGH ENERGY PARTICLES

SINERGIE E COLLABORAZIONI: TASKs , OBIETTIVI…

SPACE IT UP!

5. PROTEZIONE DEL PIANETA

6. PROTEZIONE INFRASTRUTTURE CRITICHE E SPACE WEATHER

7. SVILUPPO SOSTENIBILE DEL PIANETA

8. ESPLORAZIONE UMANA E ROBOTICA, Tech

9. HABITAT, SCIENCE

ESPLORAZIONE EXTRATERRESTRE

DISCIPLINE CONDIVISE

esa BUSINESS INCUBATION CENTRE TURIN

VENTURING IN SPACE

I3P INCUBATORE POLITECNICO DI TORINO

Politecnico di Torino 1859

FONDAZIONE links PASSION FOR INNOVATION

REGIONE PIEMONTE

Fondazione Compagnia di San Paolo

CAMERA DI COMMERCIO INDUSTRIA ARTIGIANATO E AGRICOLTURA DI TORINO

https://www.esabic-turin.it/

→ THE EUROPEAN SPACE AGENCY

Contatti

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#INNOVATION @DET

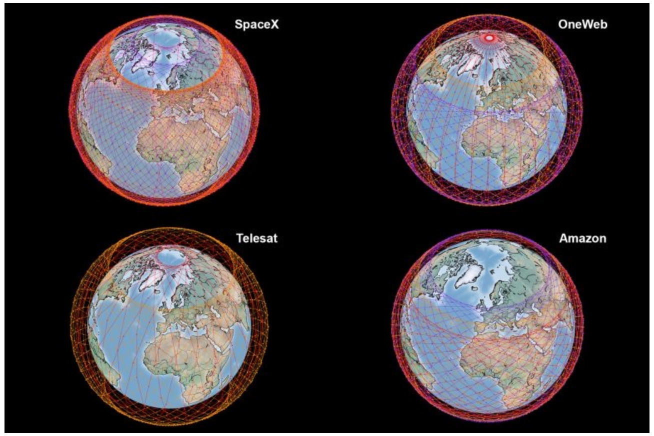
Satellite networks

P.Giaccone

Politecnico di Torino
1859

Satellite mega constellations and networks

- communications
  - ground station <-> satellite
  - satellite <-> satellite
- packet network
  - store & carry & forward
  - multihop
- network topology
  - dynamic
  - predictable
  - periodic
- very large number of nodes (1k-10k)

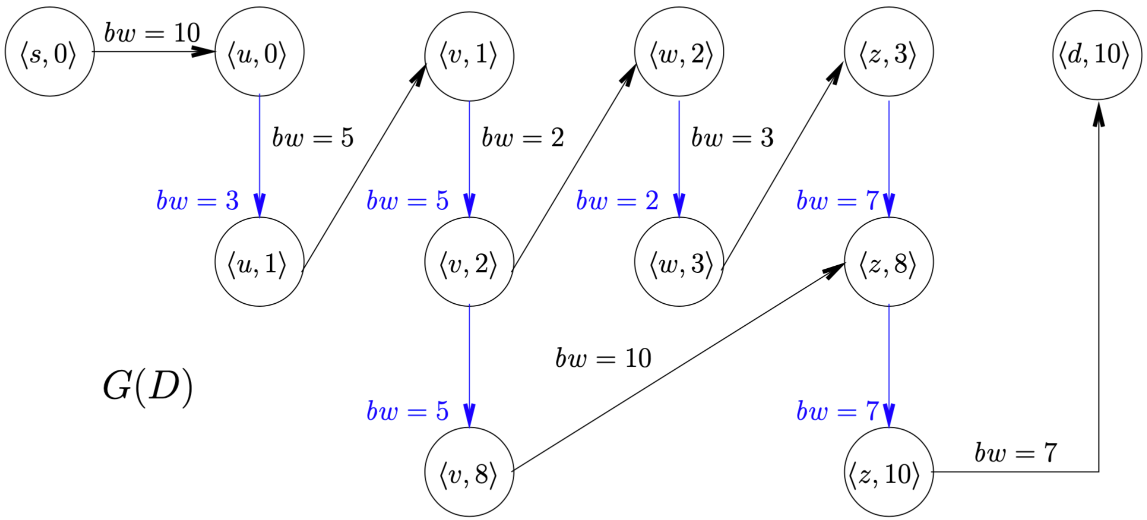


Performance evaluation and optimization

- network algorithms and procotols must be tailored and optimized for satellite networks
- scalable simulation and modeling approaches are required
- example of questions to address
  - what is the maximum overall capacity of a satellite network given a traffic matrix?
  - what is the minimum communication latency between two ground stations?
  - what are the best settings for a given protocol or algorithm?

Methodology

- scalable network simulations based on fluid models
  - adopted in the past to simulate large data centers with thousands of nodes
- formal methods based on time-expanded graphs



Contatti

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www.ecs-nodes.eu/1-aerospazio-e-mobilita-sostenibile

By DALL·E 3

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Radio Navigation Solutions for Harsh Environments

F. Dovis, A. Minetto, **A. Nardin,** I. E. Mehr

Politecnico di Torino

1859

Contesto e competenze

Navigation Signal Analysis and Simulation Research Group

Il gruppo NavSAS svolge attività di ricerca nel campo dei sistemi di **navigazione satellitare**

- Signal processing per **Positioning, Navigation, and Timing**
- Approccio teorico e simulativo integrato da competenze sperimentali
- Dalla ricerca di base alla pre-prototipazione delle soluzioni
- Forte reputazione e riconoscimento internazionale

Contesto e competenze

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FACT SHEET, dal 2001

25 Studenti Ph.D.
15 Ricercatori Under Grant

30 Progetti Europei
2 Coordinamento Progetti Europei
3 Progetti Regionali
10 Contratti industriali

Ricevitori GNSS e tecnologie

- Software Defined Radio receivers
- Ricevitori GNSS per lo spazio
- Riflettometria GNSS
- Post-processing di dati GNSS grezzi da smartphone

Advanced Signal Processing

- Multipath Detection e Mitigation
- Integrazione multisensore
- Posizionamento cooperativo
- Machine Learning applicato al GNSS

Interferenze naturali GNSS

- Rilevamento degli effetti di scintillazione ionosferica sui segnali GNSS
- Algoritmi di machine learning per il rilevamento automatico
- Robust Monitoring Receivers

GNSS Jamming e Spoofing

- RF threats Impact Assessment
- Jamming Detection/Mitigation
- Spoofing Detection/Mitigation

Applicazioni

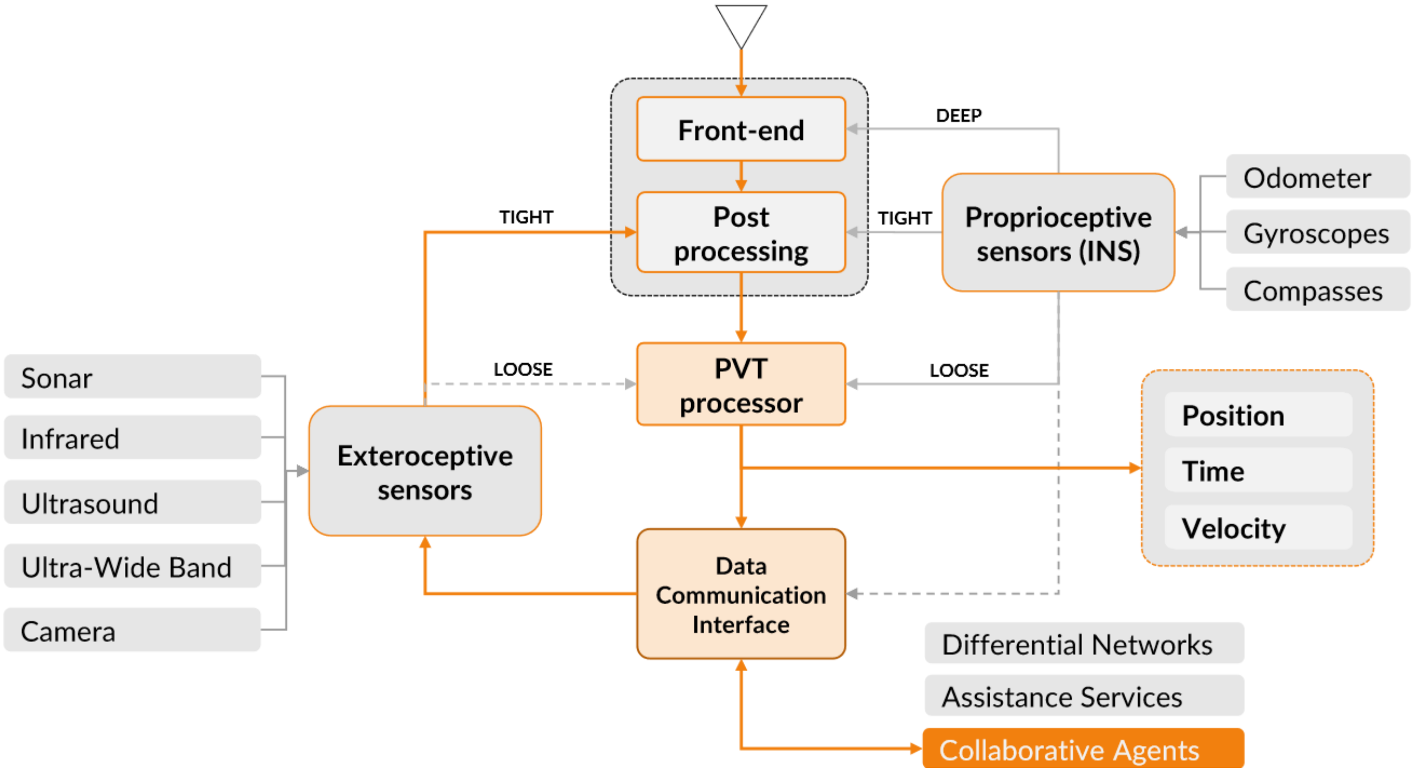
- UAV/UGV Navigation (PIC4SER)
- Reti veicolari
- Applicazioni spaziali

Contesto e competenze

Navigation Signal Analysis and Simulation Research Group

Competenze offerte

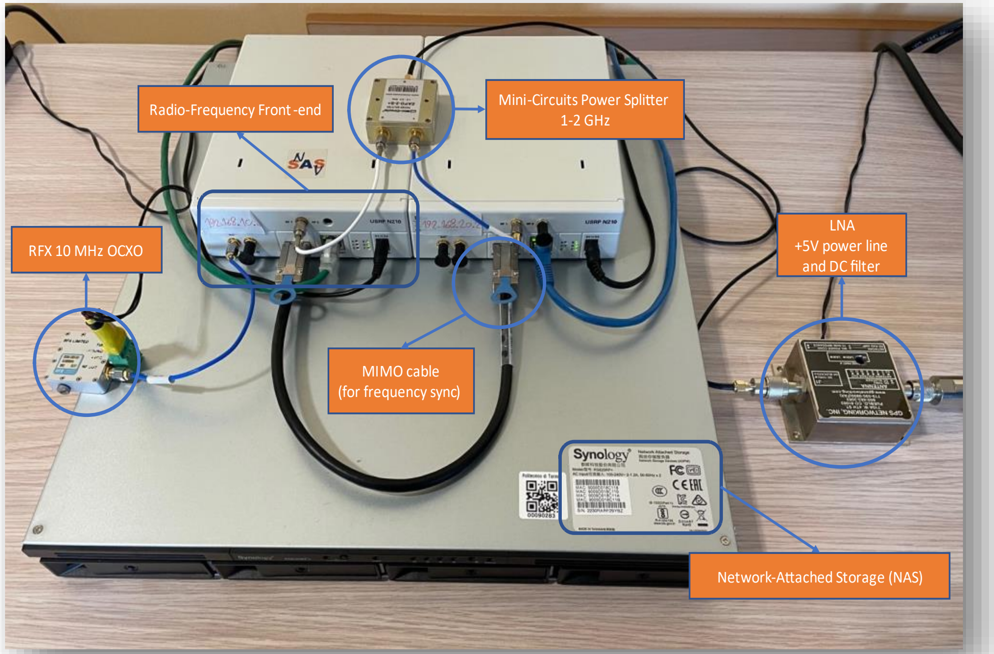
- Design di **ricevitori GNSS** standalone e integrati con altri **sensori**
- Sviluppo di algoritmi per **multipath detection** e correzioni
- Soluzioni avanzate di posizionamento (cooperative positioning) per **smartphones**, **veicoli** e **droni**
- Integrazione con sistemi di telecomunicazioni (NavCom, 5G – NTN, LEO-PNT)
- Test-bench di laboratorio
- Interference detection



Soluzioni sviluppate / 1

N-SMART
Navigation - Signal Monitoring, Analysis and Recording Tool
Acquisizione e monitoraggio continuo di campioni di segnale GNSS multifrequenza

- N-SMART cattura campioni digitali di segnale ad **alta fedeltà**, in fase/quadratura (IQ) e a frequenza intermedia (IF)
- Installazione e deployment **compatte** e immediate
- Rilevamento e classificazione automatizzati degli **interferenti** a radiofrequenza (RF)



Componenti

Soluzioni sviluppate / 1

N-SMART
Navigation - Signal Monitoring, Analysis and Recording Tool

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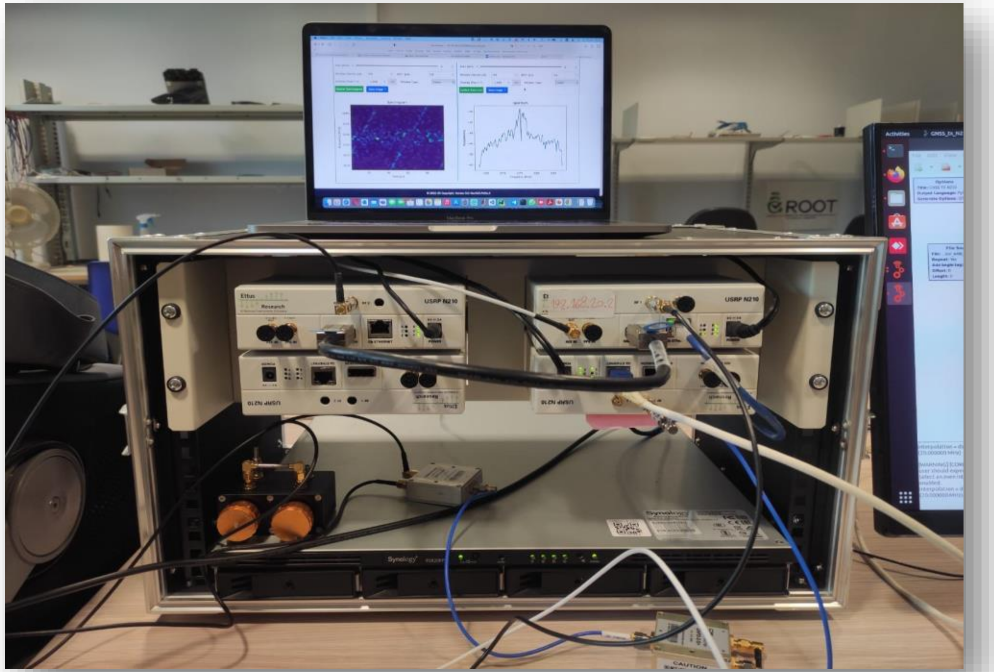


Prototipo

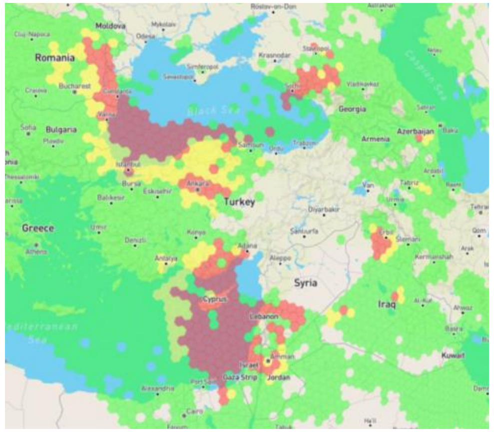
Soluzioni sviluppate / 1

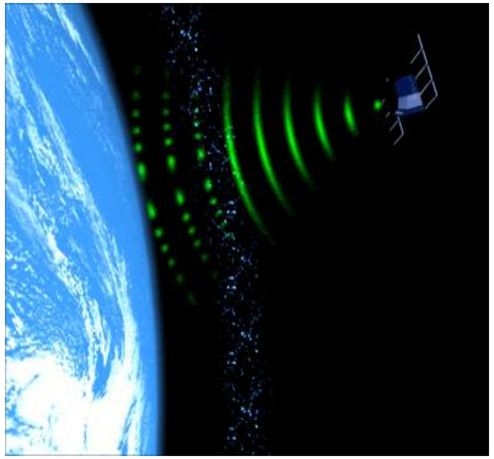
N-SMART
Navigation - Signal Monitoring, Analysis and Recording Tool

Acquisizione e monitoraggio continuo di campioni di segnale GNSS multifrequenza

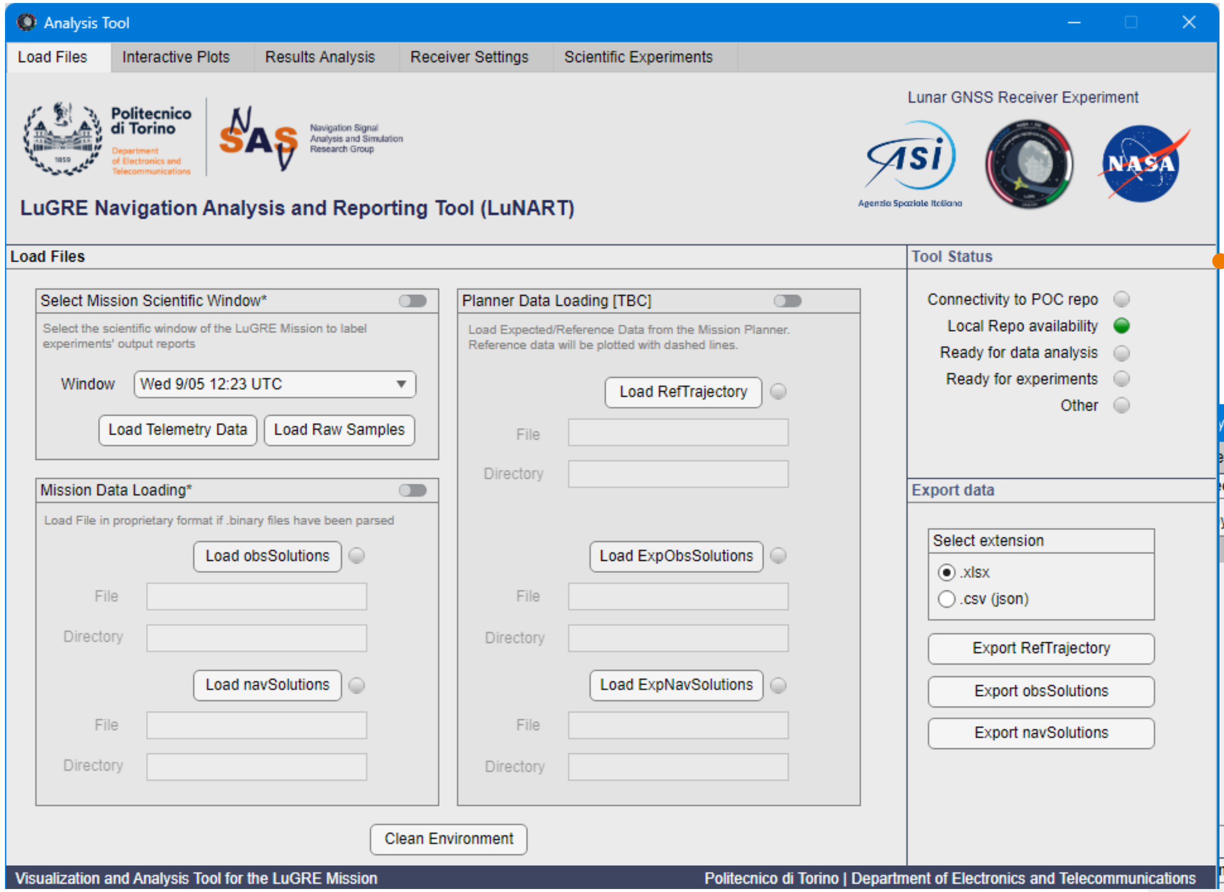
Perchè monitorare segnali GNSS?

- Interferenza intenzionale e non
  jamming | spoofing
- Space Weather
  Scintillazioni | Tempeste Geomagnetiche
- R&D nuove tecnologie
  signal design | Receiver design
- Analisi forense
  data labelling | timestamping

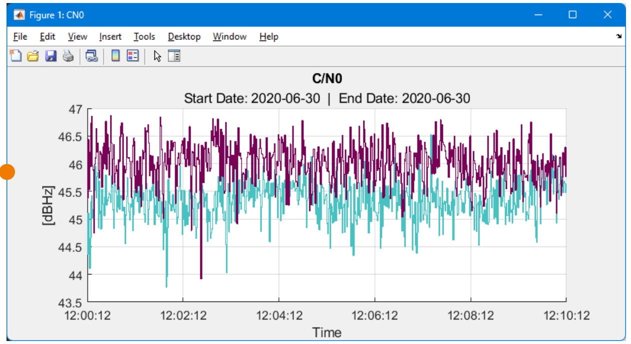



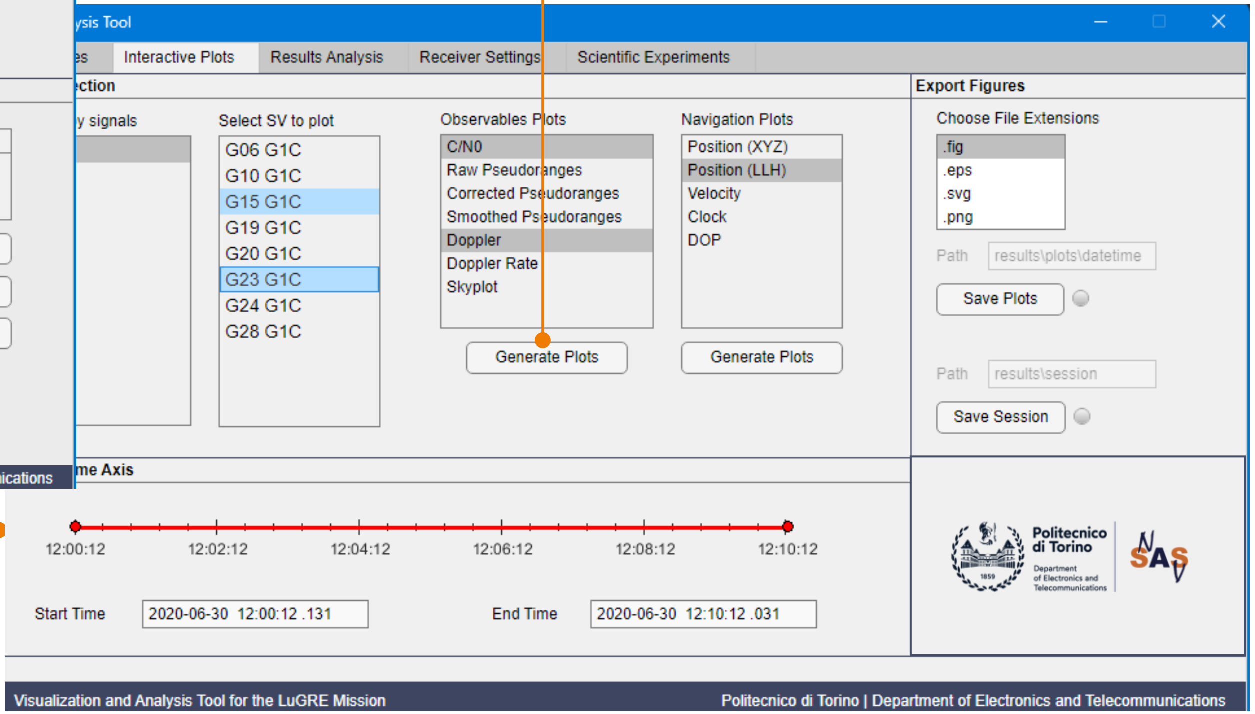
Soluzioni sviluppate / 2



Control Panel

Pannelli principali dello strumento di analisi e integrazione dati





File Loader

Caricamento dati GNSS da ricevitori remoti

Data Quick Look

Analisi interattiva con timeline di acquisizione dati

Contatti

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#INNOVATION @DET

Deep learning for satellite image processing

E. Magli, D. Valsesia

Politecnico di Torino

1859

Contesto e competenze

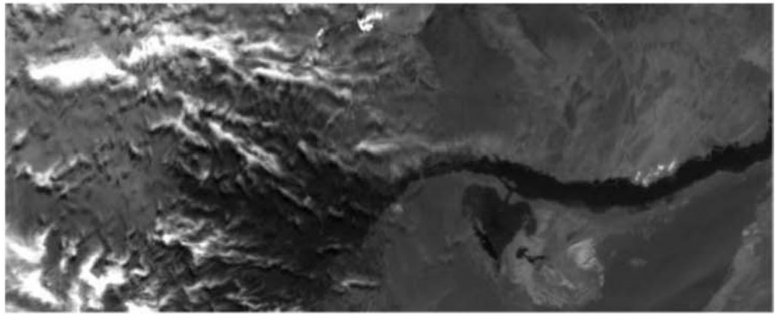
Gruppo di ricerca «**Image Processing Lab**», focalizzato su deep learning con applicazioni a **spazio** (a bordo e a terra)

- *Reti neurali* avanzate: transformer, graph neural networks, GAN, reti ricorrenti, …
- *Training* avanzato: supervised, self-supervised, adversarial, …
- *Problemi* affrontati:
  - Elaborazione immagini: deconvoluzione, denoising, super-resolution
  - Analisi immagini: classificazione, segmentazione, object detection
  - Predizione temporale da sequenze di dati (p.es. space weather)

Elaborazione a bordo del satellite

Competenze

- Compressione a bordo
- Cloud screening
- Analisi di immagini
- Computational imaging



Esperienze specifiche

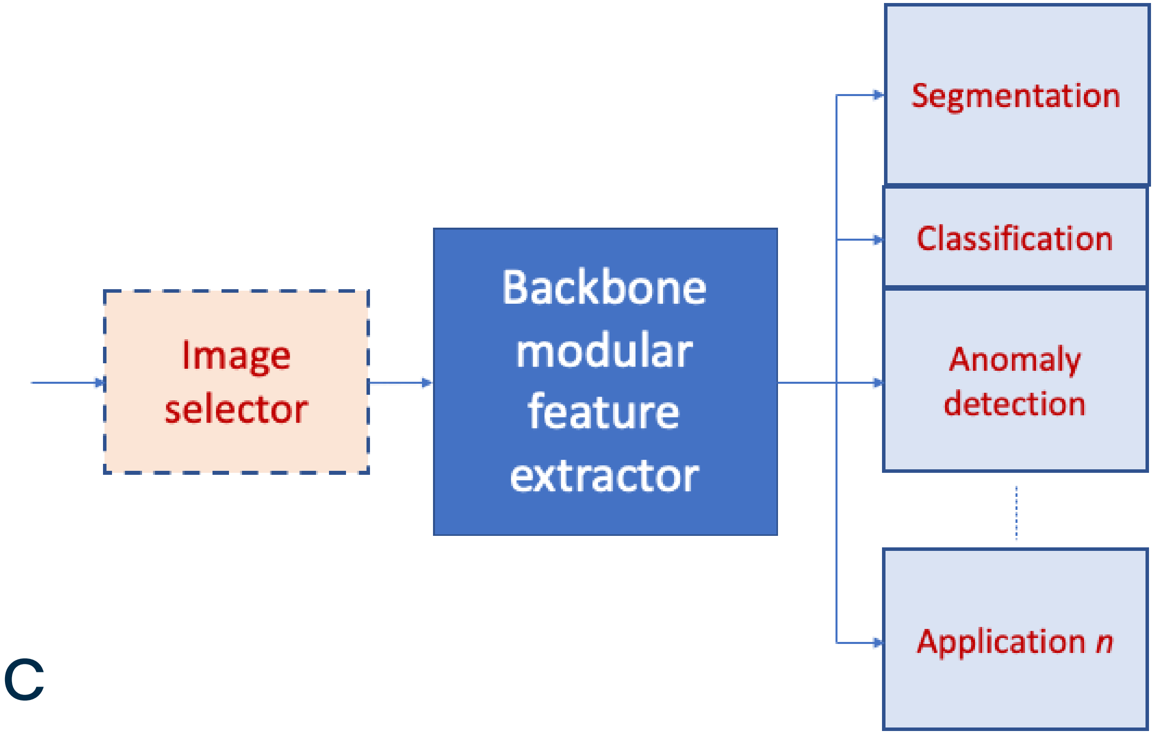
- H2020 EO-ALERT, SURPRISE
- ESA CHIME, ESA Sentinel-2 Next generation
- Attività con ESA, ASI, CGS, OHB, Deimos, DLR, Techno System, …

Self-supervised learning per edge-AI

Problema: scarsità di dati etichettati, complessità

Soluzione: piattaforma con feature extractor condiviso

- Addestrato in modo auto-supervisionato
- «Teste» addestrate con pochi dati
- Attività svolta in collaborazione con Argotec e Ithaca



«Enhancement» di immagini

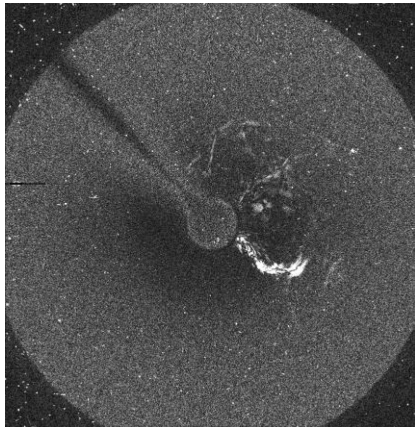
Obiettivo: ricostruire immagini con caratteristiche migliori

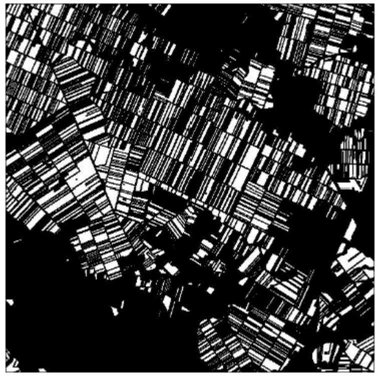
- Deconvoluzione (inversione della PSF dello strumento)
- Super-resolution
  - Single- e multi-image
  - Guidata da un sensore ad alta risoluzione
  - Non supervisionata
- SAR image despeckling (self-supervised)
- Pan-sharpening

- Attività con Leonardo, CNR, ACRI, Fraunhofer HHI, …

Analisi di immagini

- Cloud screening
- Image classification and segmentation
- Object detection
- Data fusion
- Change detection → a bordo! (Attività ongoing con ESA)





Implementazione «embedded»

Obiettivo: realizzare reti neurali a throughput elevato e basso consumo energetico

- Reti neurali con parametri e attivazioni binarie {-1,1} e ternarie {-1,0,1}
- Realizzabili con sole somme e sottrazioni
- Si prestano a implementazioni particolarmente efficienti

Contatti

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ASTRACOM

R. Garello

Politecnico di Torino
1859

ASTRACOM

Roberto Garello (Associate Professor)

Monica Visintin (Associate Professor)

Riccardo Tuninato (PhD student, Garello, cycle 36)

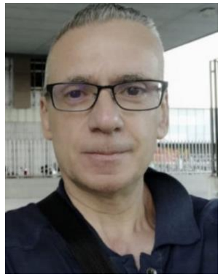
Gabriel Maiolini Capez (PhD student, Garello, Fraire, cycle 37)

Riccardo Schiavone (PhD student, Garello, Visintin, Liva, cycle 37)

Alessandro Compagnoni (PhD student, Chiasserini, Garello, cycle 39)

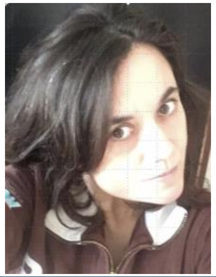
Giusi Alfano (postdoc research assistant)

Daniel Gaetano Riviello (postdoc research assistant)










Collaborations

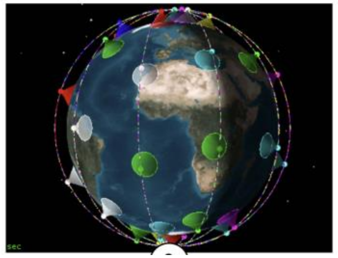
RESEARCH

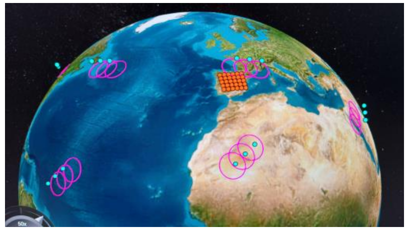
- Carla Fabiana Chiasserini, Fabio Dovis and NavSAS group, Marco Pirola, Giorgio Taricco - Politecnico di Torino - DET
- Alessandro Nordio and Giuseppe Virone - CNR-IEIIT
- Juan A. Fraire - INRIA Lyon, France
- Gianluigi Liva - DLR, Germany
- Emanuele Viterbo - Monash University, Australia

COMPANIES (last 5 years)

- Argotec
- Deimos
- Eutelsat
- Telespazio
- Thales Alenia Space Italia
- Vyoma

1. Satellite Constellation Design





- Regional and Global coverage
- Sporadic and continous connection
- Walker, Flower, ad hoc, …

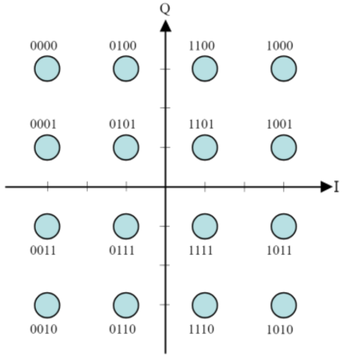
ESA – Friisat (to start in Q4 2024)

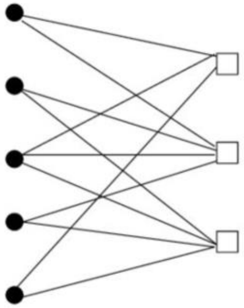
2. Space Communication Systems

- System design, analysis, simulation
- TT&C
- Space segment and Ground segment
- Link Budget

ESA/Deimos - Nextrack (completed)
ESA/Deimos - Nexcode (completed)

3. Physical Layer



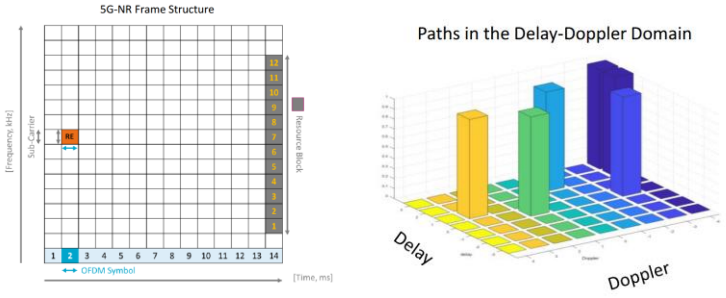


- Modulations
- Digital Signal Processing
- Synchronization
- Error Correcting codes
- Spreading sequences

[NO RF, NO Antenna, NO Optical]

Argotec – ERMES (completed)
ESA/TASI – MASSCON (ongoing)

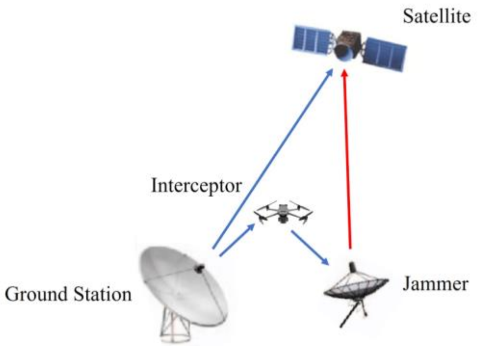
4. 5G NTN Performance Evaluation, OTFS for 6G



- 5G NTN OFDM
- 6G OTFS

ESA – 5G NTN (ongoing)

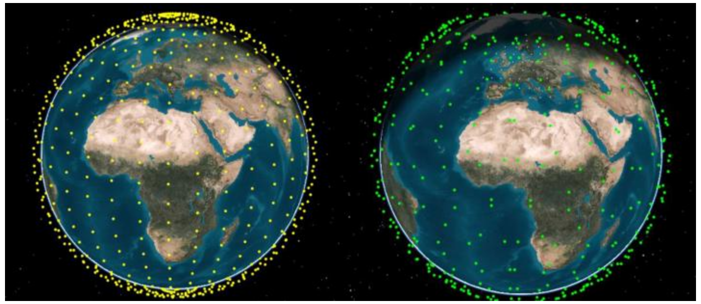
5. Jamming Detection and Mitigation



- ML-based detection
- OTFS countermeasures
- Design of binary sequences with TRANSEC

EU – 6Galaxy (proposal for Q1 2025)

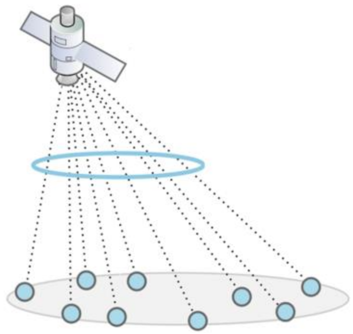
6. Handover, Routing, Radio Resource Management for LEO/VLEO constellations



- VLEO constellation design
- Study of algorithms
- Performance Evaluation

ESA – HANDING OVER (to start in Q4 2024)

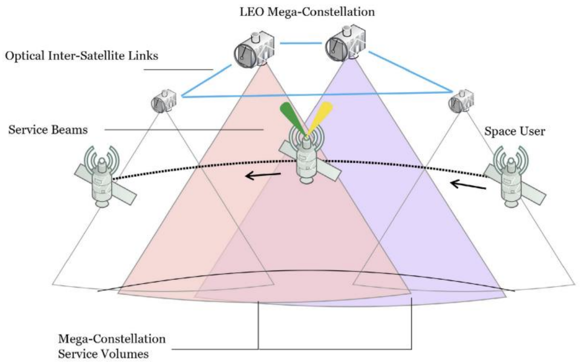
7. Direct-to-Satellite Internet of Things, Massive Multiple Access



- Sparse constellations for LoRa
- E-SSA enhanced versions

INRIA, DLR (ongoing)

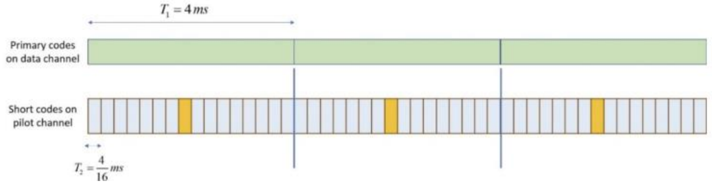
8. Mega-Constellation Services for LEO Satellites



- New paradigm
- Performance evaluation
- Transceiver initial design

ESA/Vyoma – MCSS (completed)

9. Pilot Channels for LEO positioning



Data-less pilot channels for MEO and LEO GNSS to speed up initial acquisition (PATENT)

CSP/POC (ongoing)

What are we looking for?

- Partnerships for joint projects (national, ESA, EU, …)
- Industrial partners for
  (i) design of LEO transceiver for Mega-Constellation Services in Space
  (ii) LEO positioning patent
- Proposals for new research topics
- Thesis hosted by companies

1. **Satellite Constellation Design**
2. **Space Communication Systems, TT&C**
3. **Physical Layer, Modulations, Coding, …**
4. **5G NTN, OFDM/OTFS**
5. **Jamming Detection and Mitigation**
6. **Handover, Routing, Radio Resource Management**
7. **Direct-to-Satellite Internet of Things**
8. **Mega-Constellation Services for LEO Satellites**
9. **Pilot Channels for LEO positioning**

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di Torino

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Elettronica a RF e microonde per lo spazio

C. Ramella, M. Pirola,
V. Camarchia, G. Ghione

Politecnico di Torino
1859

Contesto e competenze

- Caratterizzazione, modellistica e progetto di dispositivi, circuiti e sistemi ad alta frequenza
- Progetto e ottimizzazione di circuiti avanzati ibridi (MIC) e integrati (MMIC)
- Frequenze: RF, microonde, onde millimetriche
- Tecnologie: GaAs, GaN, HEMT, HBT
- Applicazioni: Telecomunicazioni (5G/6G, satcom), P2P radio, radar

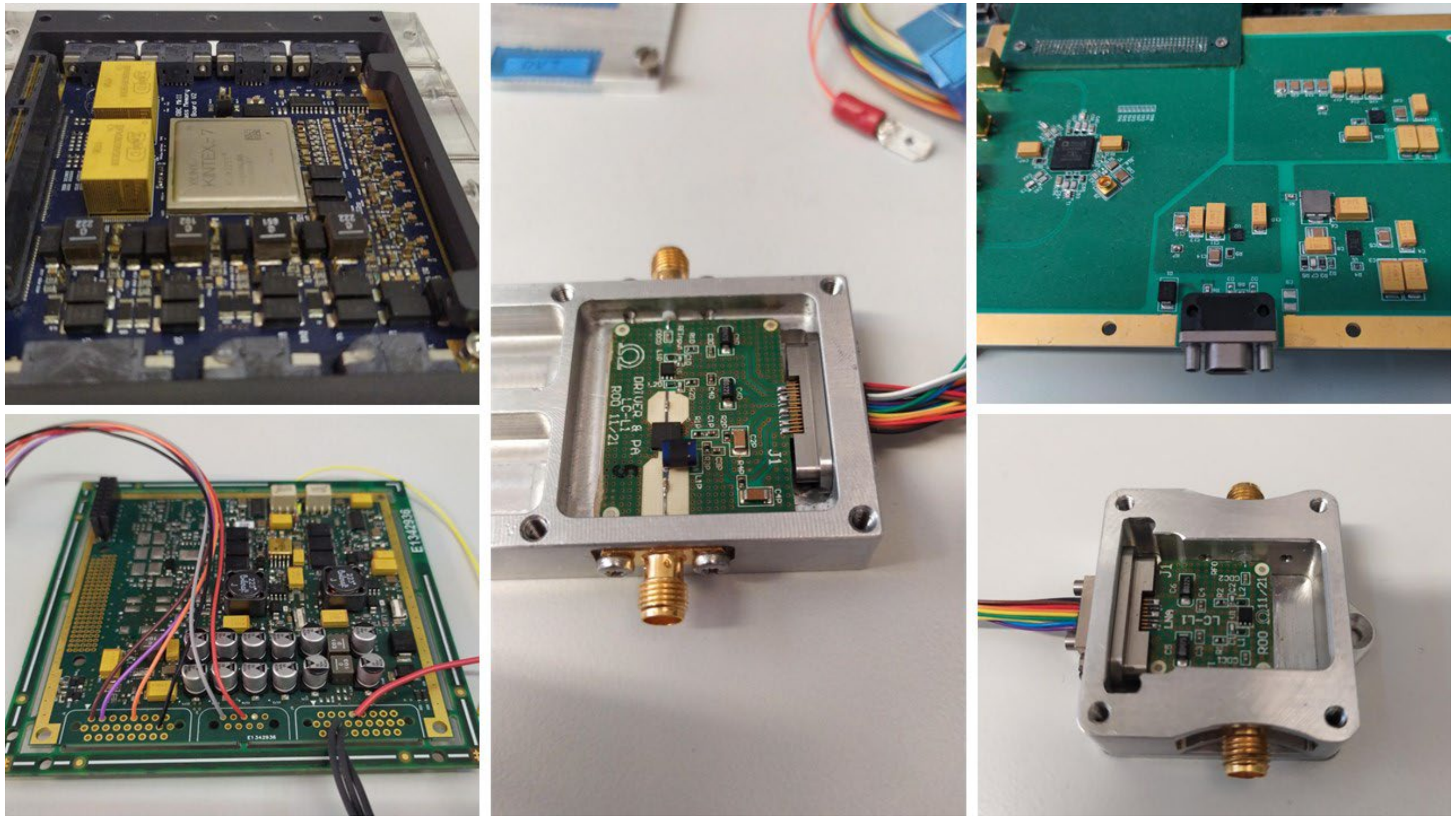
Cooperazioni attive

- PoliTo è tra i membri fondatori del *Microwave Engineering Center for Space Applications*: un consorzio interuniversitario che riunisce 14 gruppi di ricerca di eccellenza nel campo dell'elettronica ad alta frequenza per applicazioni spazio
- MECSA/PoliTo cooperano all'interno di svariati progetti sponsorizzati da ESA e ASI

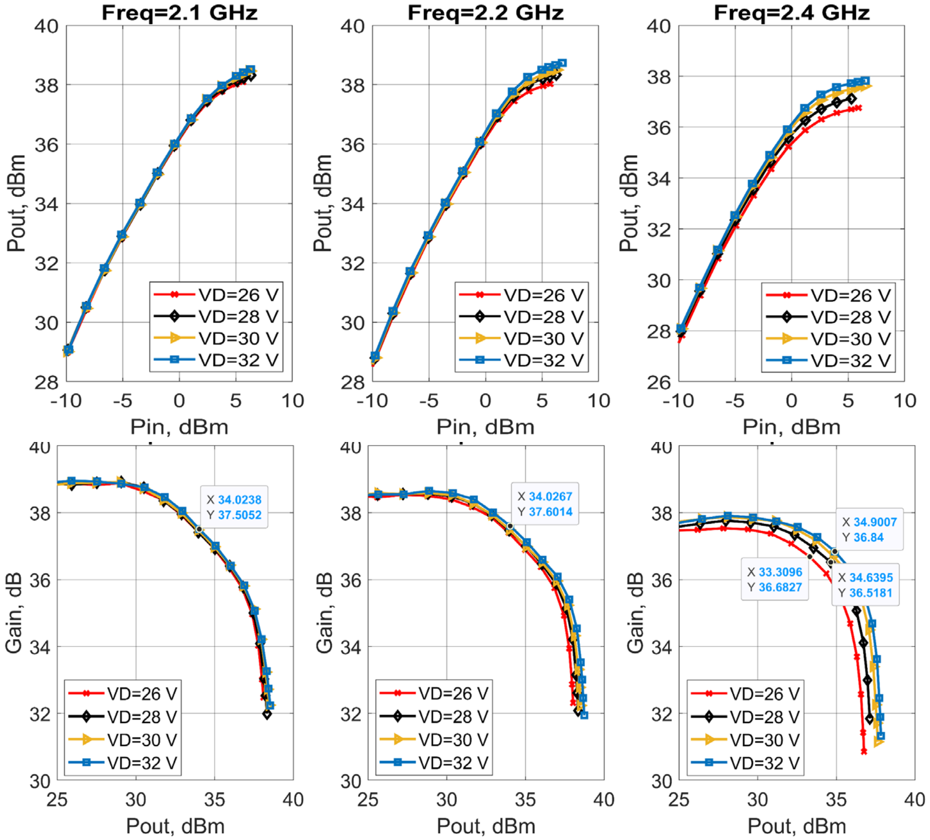
Cooperazioni attive

- Università italiane
  - Roma TVG, UniPD, PoliMI, UniFI, UniMiB, …
- Università straniere
  - Aveiro, Cardiff, Santander, …
- Aziende internazionali e *km 0*
  - QORVO, ESA, ASI, TAS-I, UMS, OMMIC, Leonardo
  - ARGOTEC

ERMES – European Radio Module for advancEd Spacecrafts (closed/approved 2024)



- 6 W Pout - 40% PAE – 28 dB Gp



argotec
SPACE FOR AMBITIONS

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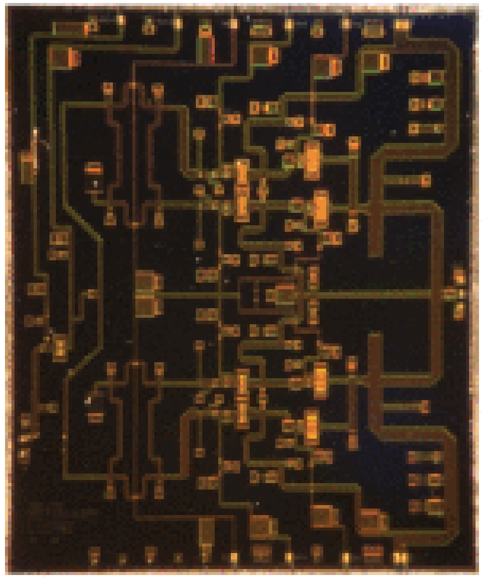
NEOHM
DIVISIONE ELETTRONICA
ALUTRON

Progetti ESA

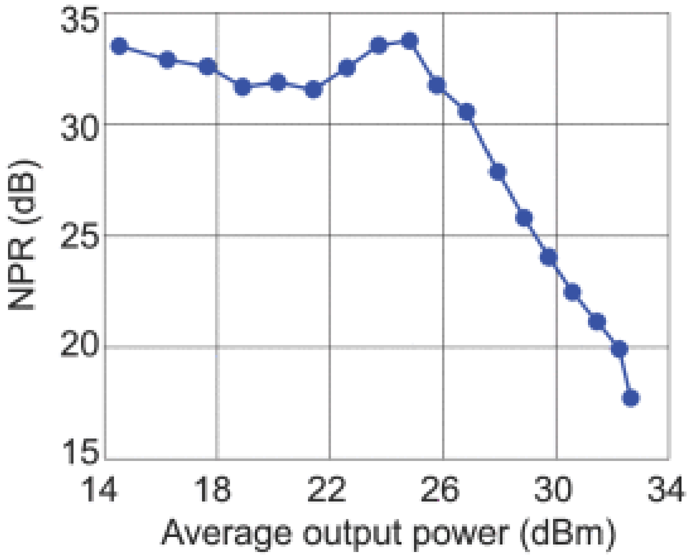
- Progetto di amplificatori di potenza per applicazioni satcom

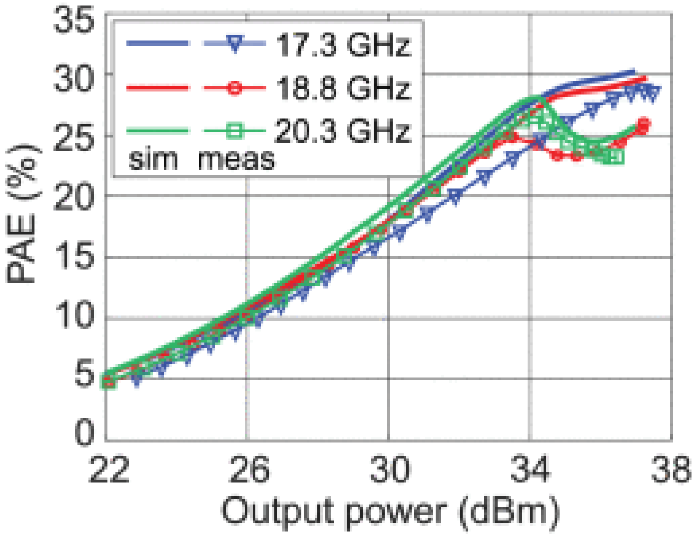
Esempio: Amplificatore Doherty ad alta linearità

- 16.3 – 20.3 GHz
- 5 W Pout
- > 23% PAE
- > 18 dB Gp
- > 17dB NPR
- OMMIC GaN/Si



5x6 mm²



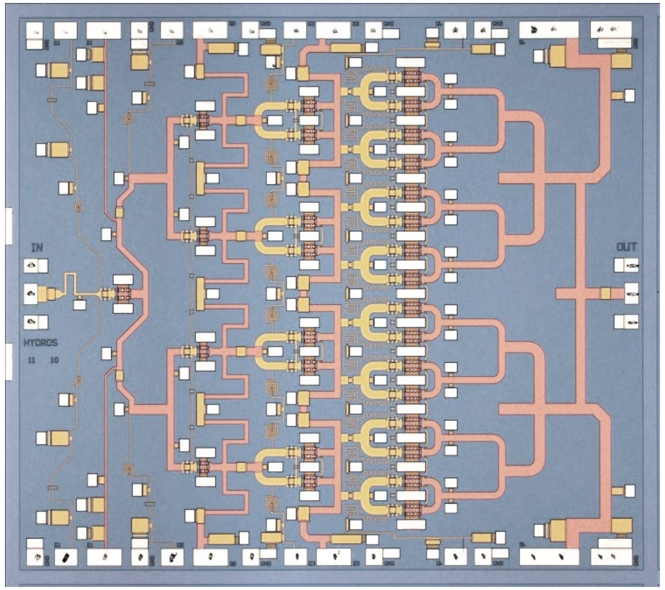


Progetti ESA

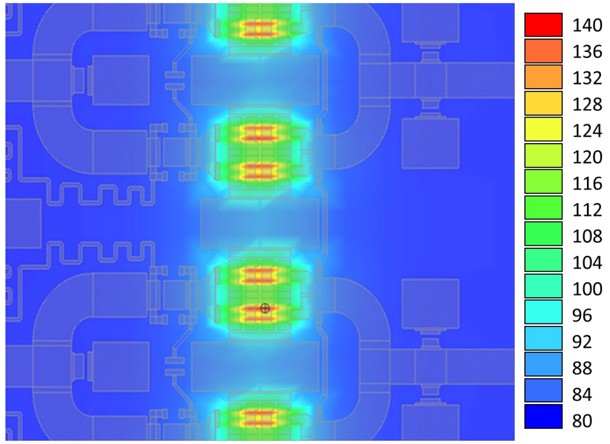
- Progetto di amplificatori di potenza per applicazioni remote sensing

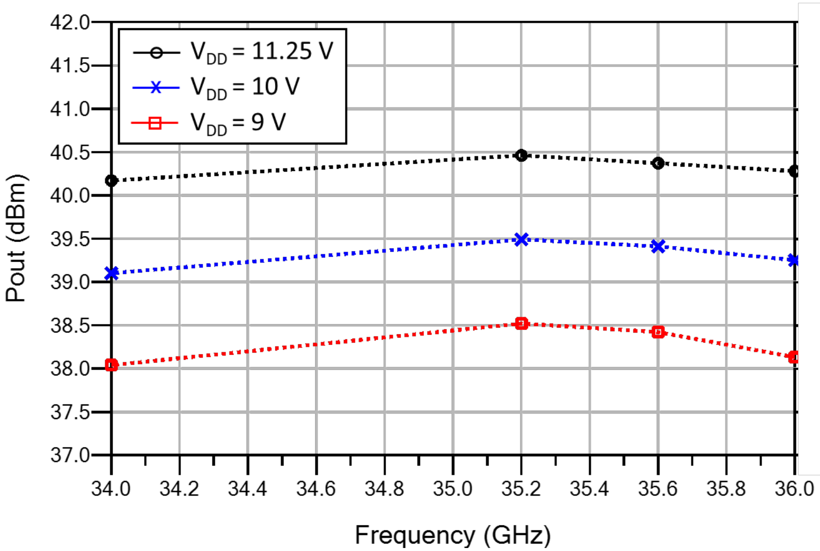
Esempio: Amplificatore banda Ka

- 35.2 – 36 GHz
- 6.6 W Pout
- 20% PAE
- 20 dB Gp
- 140°C max Tj
- OMMIC GaN/Si



4.5x4 mm^2

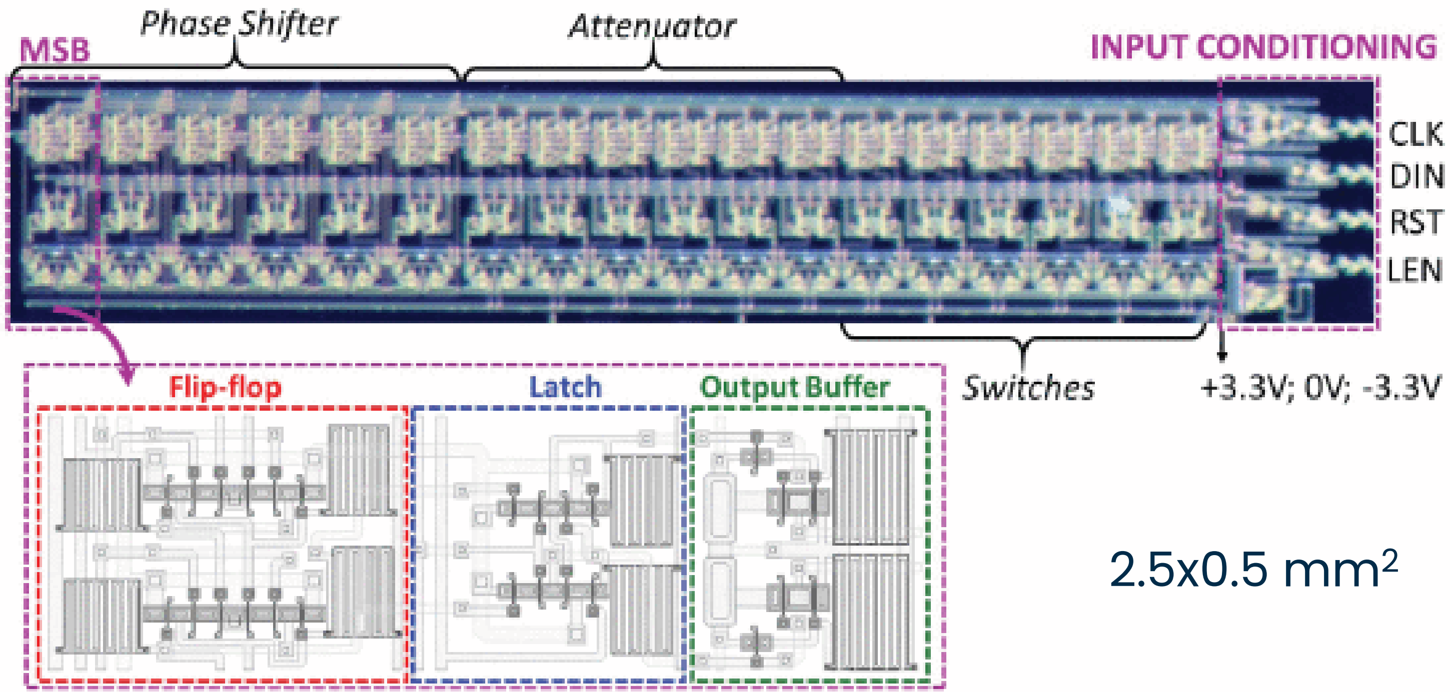




Progetti TAS-I

- Progetto di un convertitore seriale-parallelo a bassissimo consumo in GaAs per un sistema AESA di comunicazione satellitare (core-chip)

  - 18-bit
  - 2.2 mW/bit
  - > 50 MHz
  - 87% yield
  - Win GaAs



2.5x0.5 mm²

  - Sviluppo di un modello ad-hoc per la simulazione time-domain del sistema (>500 HEMTs)

Contatti

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Photonics for the space sector

Paolo Bardella, Andrea Carena, Vittorio Curri

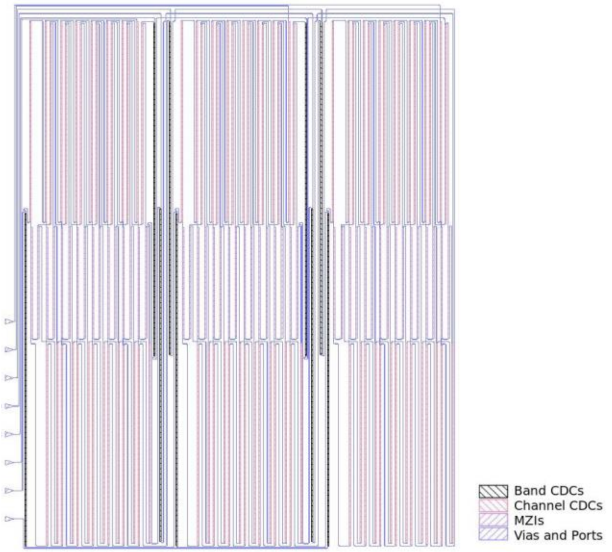
Politecnico di Torino
1859

Contesto e competenze

- La fotonica riveste un'importanza crescente nell'industria aerospaziale:
  - Le comunicazioni tra satelliti usano sempre più spesso transceiver ottici (bassa latenza, alta velocità, maggiora banda)
  - I sistemi di comunicazioni coerenti (usati nelle comunicazioni su fibra ottica) permettono ai satelliti di raggiungere velocità di comunicazione ancora maggiori, alta sensitività e SNR
    - I componenti ottici integrati sono parti fondamentali per lo sviluppo di sistemi di comunicazione leggeri, robusti, a basso consumo ed elevata capacità
  - L'*astrofotonica* utilizza circuiti ottici integrati per applicazioni spettroscopiche, per imaging ad alto contrasto, metrologia,...

Soluzioni disponibili

- Approccio verticale alla progettazione di circuiti fotonici integrati
  - Dal progetto di singoli componenti ottici fino alla caratterizzazione del sistema completo da un punto di vista telecom
  - Software commerciali o sviluppati ad hoc
  - Fino ad alcune centinaia di componenti per circuito
  - Collaborazioni sullo studio degli effetti delle radiazioni ionizzanti sui componenti ottici integrati



- Esperienza ventennale nell’analisi di sorgenti laser quantum well e quantum dot
- Possibilità di caratterizzazione di sistemi ottici integrati e laser presso il centro interdipartimentale PhotoNext

Contatti

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#INNO
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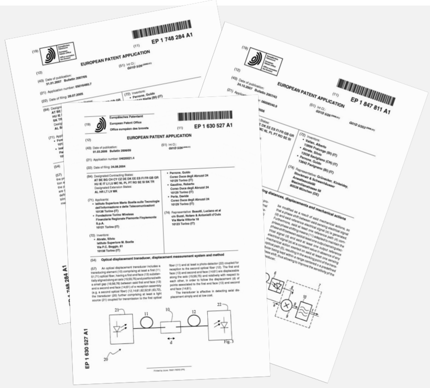
Tecnologie fotoniche per aerospazio

G. Perrone, A. Vallan, M. Olivero, V. Serafini, A. Bellone, C. Bellezza-Prinsi, M. Cavagnetto, A. Mauro

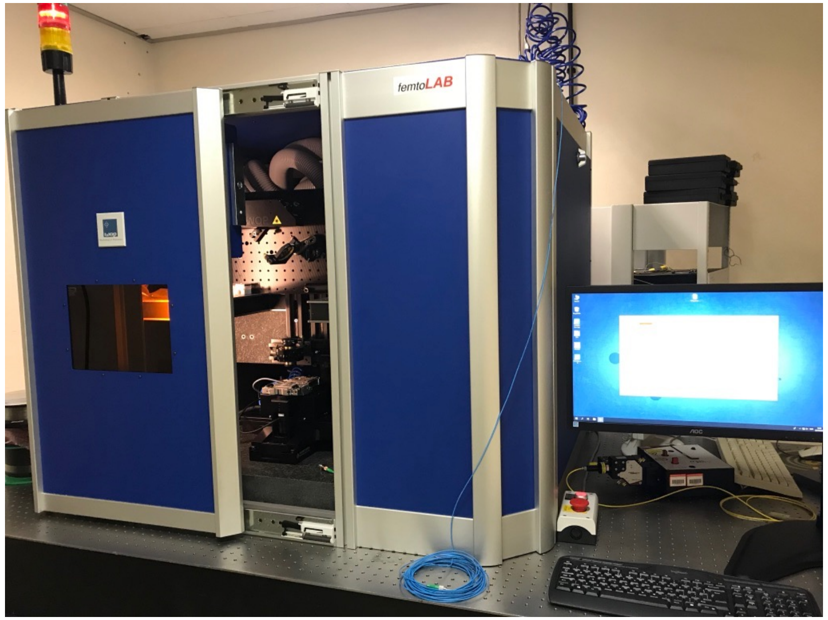
Politecnico di Torino
1859

Competenze

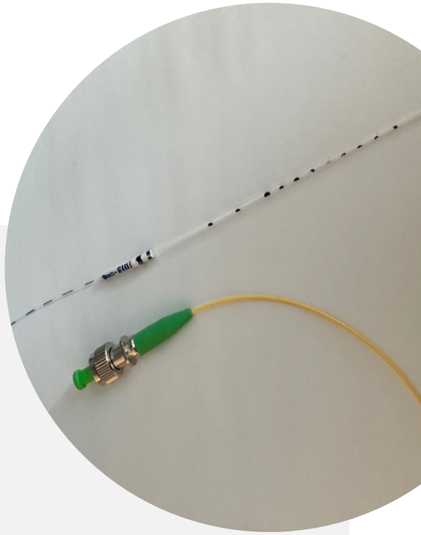
- *Gruppo di ricerca con 80+ anni di esperienza complessiva, 10+ brevetti, 200+ pubblicazioni.*
- *Sinergia con Infrastruttura di Ricerca FIP e Centro Interdipartimentale PhotoNext.*



- Realizzazione personalizzata di …
  - … sensori in fibra ottica e strumenti di interrogazione e analisi dei dati;
  - … sistemi per la generazione e gestione di fasci laser di alta potenza (kW).

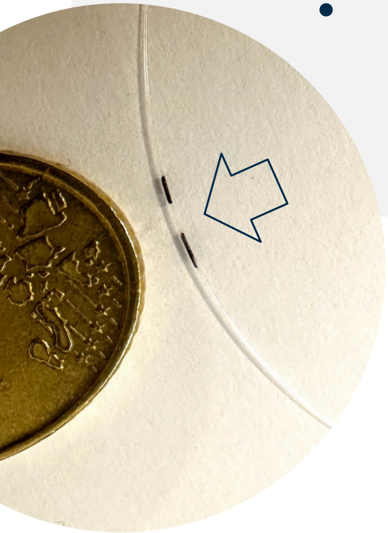


Sensori in fibra ottica



Perché sensori in fibra ottica?

- Ridotto impatto invasivo: leggerezza, flessibilità, versatilità.
- Immunità a disturbi elettromagnetici e impossibilità di innescare incendi.
- Possibilità di multiplazione lungo una fibra: sistemi quasi distribuiti o distribuiti.



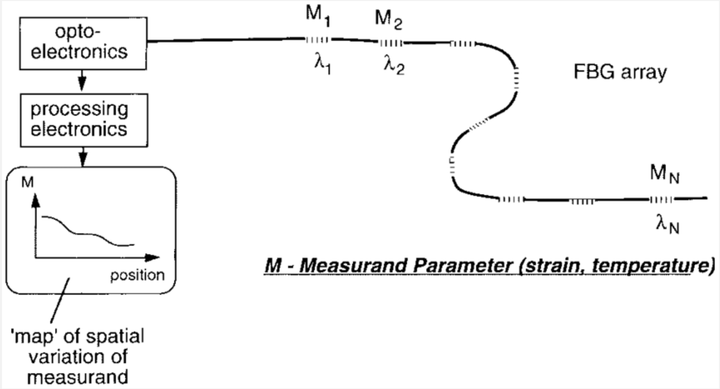
Cosa si può misurare?

- Temperatura
- Deformazioni
- Vibrazioni
- Pressione
- Alte tensioni
- Radiazioni ionizzanti

Soluzioni sviluppate / 1

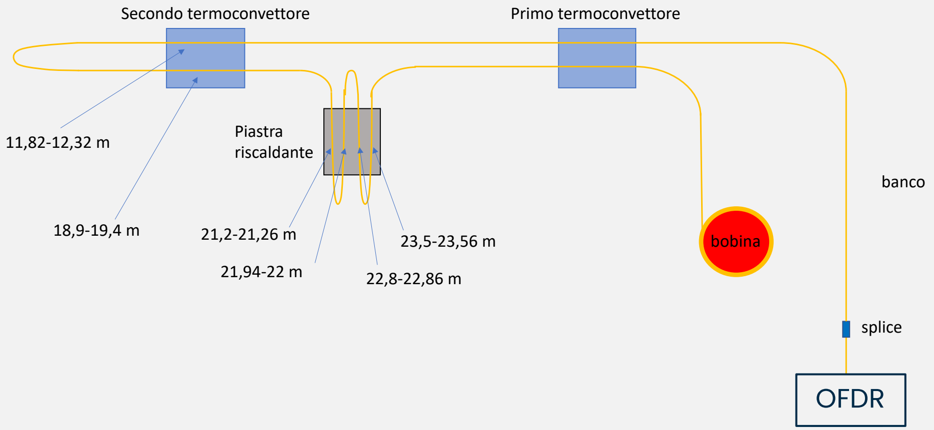
Misura quasi-distribuita di temperatura:

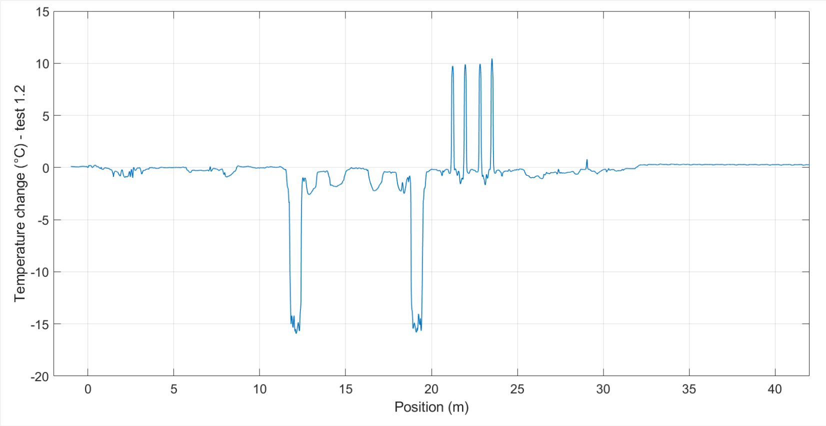
- ~ 30 sensori per fibra
- Errore < 0.05 ºC @ max 80 ºC; < 3 ºC @ max 1000 ºC
- Risoluzione spaziale ~ 1mm



Misura distribuita:

- Profili di temperatura e/o deformazione
- Risoluzione <mm @ ~20 km.





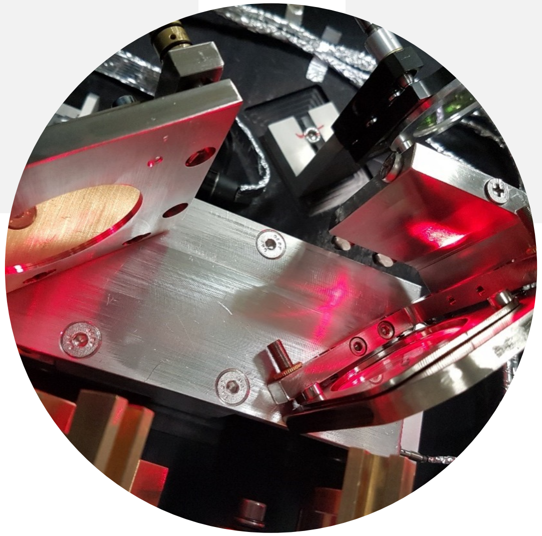
Laser e sistemi di gestioni fasci

Quali sistemi laser?

- Progettazione di laser in fibra (NIR: 1 µm – 2 µm) e a semiconduttore (blu, 800-900 nm) fino a 10-15 kW CW.
- Beam combiners e switches.

Laser nell'aerospazio?

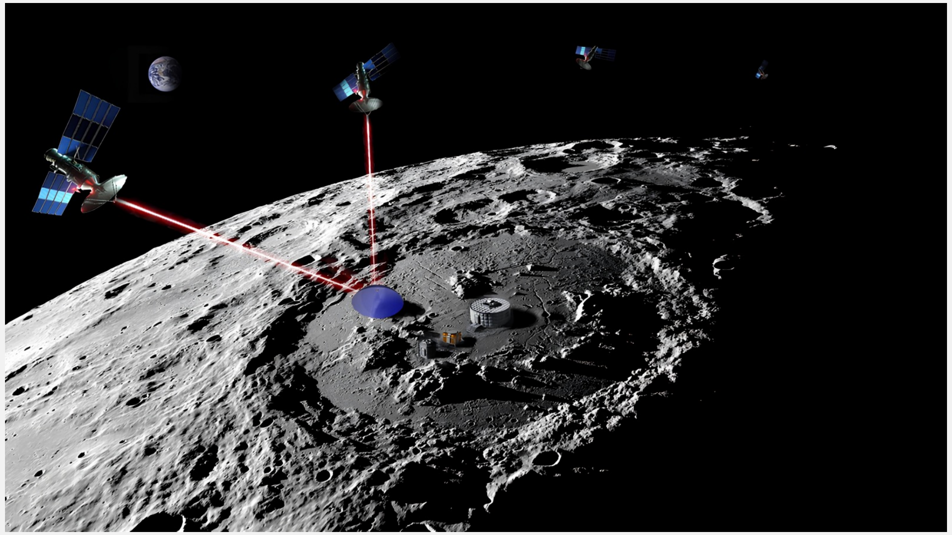
- Comunicazioni tra satelliti.
- Trasmissione wireless di energia.
- Mitigazione della «spazzatura spaziale.



Soluzioni sviluppate / 2

Generazione di energia per installazioni lunari:

- Sistemi laser e di puntamento da montare su una costellazione di satelliti in orbita lunare per trasmettere energia verso la superficie lunare.



Rendering of ORiS architecture proposal

In collaborazione con:

ORIS — ORBITAL RECHARGE in SPACE

ALITE — shedding new light

Contatti

Fiber & Laser Technologies

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- Web: https://www.polito.it/ricerca/luoghi/infrastrutture-di-ricerca/fip

Politecnico di Torino 1859

FIP Fotonica per l'Industria in Piemonte

#INNOVATION
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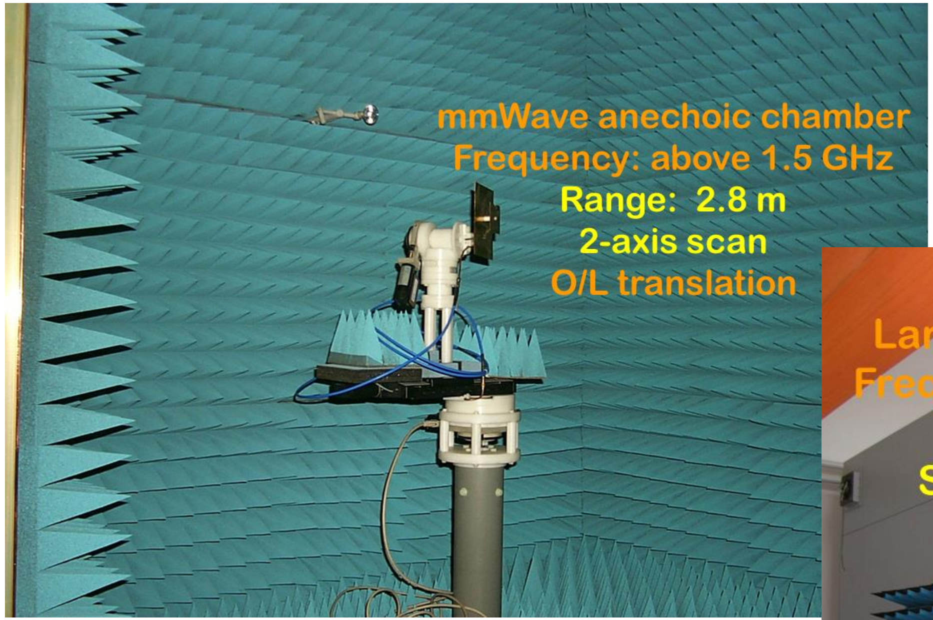
Smart Antenna and Radar Technologies

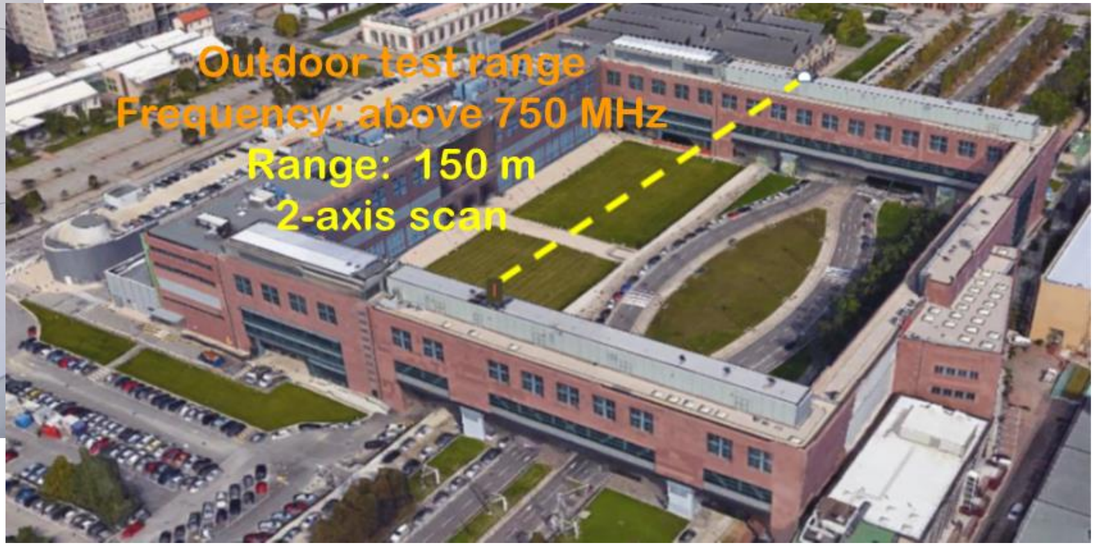
R. Maggiora

Politecnico di Torino
1859

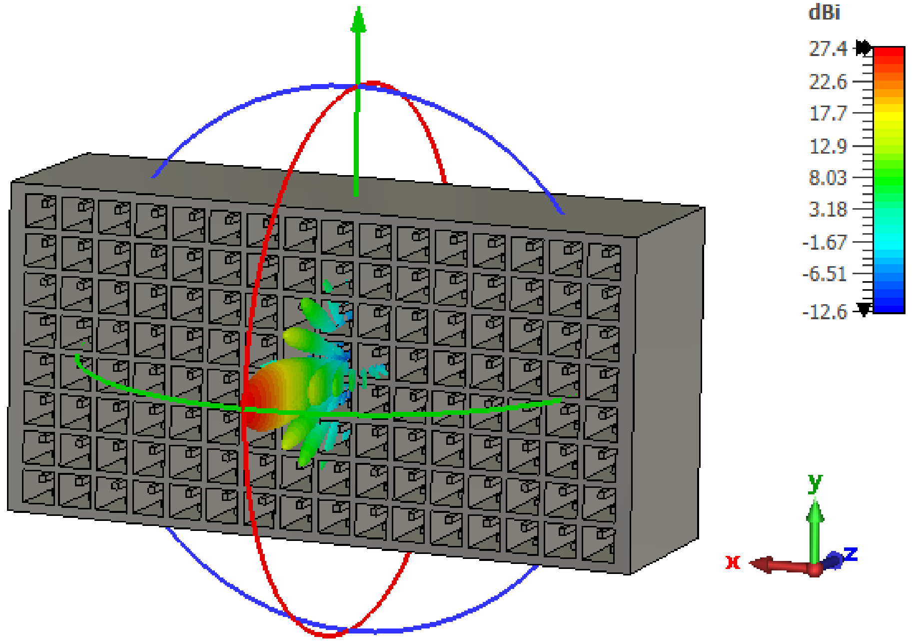
Facilities and Capabilities

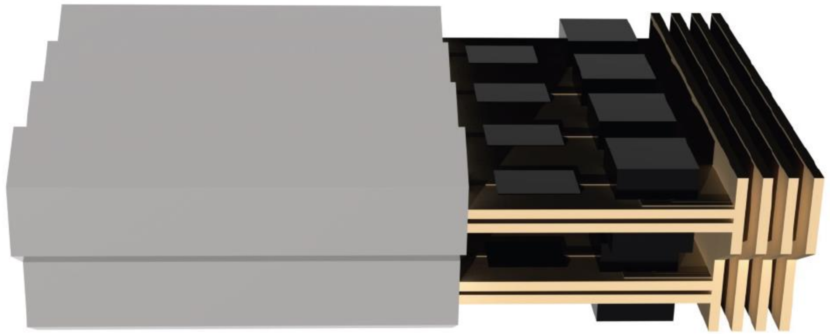


- Antennas and beamforming network design and prototyping
- Beamforming network real-time command and control system development
- Synthetic aperture radar design and prototyping



Spaceborne Ka-band phased array antenna



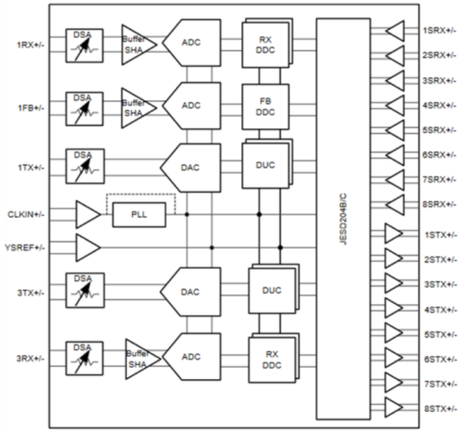


Transmit and receive dual polarization phased array active antenna tiles suitable for low-Earth-orbit missions on CubeSat platforms.

The proposed approach is for an analog beamforming antenna architecture based on commercially available beamformer chips completely controlled by a SoC.

Synthetic aperture radar T/R module

AFE7955	
Number of DACs/ADCs	4/4
Number of DUC/DDC	2/2
RF analog bandwidth	12 GHz
Max TX/RX Signal bandwidth	1200 MHz
Max ADC IF sampling rate	3 GSPS
Max DAC IF sampling rate	12 GSPS
On-chip PLL frequency	7-14 GHz



Development of an innovative, high-performance, bits to antenna, low-cost T/R module for spaceborne synthetic aperture radars based on active phased array antennas.

Contatti

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GNC for space applications
Automatica research group
Dep. of Electronics and Telecommunications
Politecnico di Torino

C. Novara, M. Pagone,
M. Boggio, C. Donati

Politecnico di Torino
1859

GNC Unit of Automatica Group

The *Automatica group* at DET-PoliTo is involved in both fundamental research and applications of methods and technologies for the analysis, identification and control of dynamical systems, efficient modeling and optimization for large-scale complex and networked systems, machine learning, data analytics, convex and nonlinear optimization.

The *GNC unit* is a subset of the Automatica group, working on **Guidance Navigation and Control** for space applications. The unit was founded by prof. Enrico Canuto (retired since 2018).

Personnel: Carlo Novara (Full Professor), Michele Pagone (Assistant Professor), Mattia Boggio (PhD student), Cesare Donati (PhD student), several master thesis students.

Expertise and Methodologies

Methodologies:

- **Control:** H-infinity, H2, LQR/LQI, optimal control, Model Predictive Control, Sliding Mode Control, Embedded Model Control, adaptive control, data-driven control.
- **Estimation/filtering:** observers for linear and nonlinear systems, Kalman filters, Extended Kalman Filters, robust filters, sliding-mode observers, augmented state observes, data-driven observers.
- **Optimization: C**onvex and nonlinear optimization. Quantum optimization algorithms.
- **Validation:** Monte Carlo simulations, robustness analysis (mu, IQC).

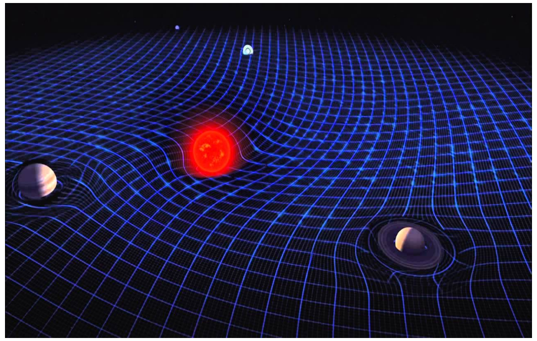
Expertise and Methodologies

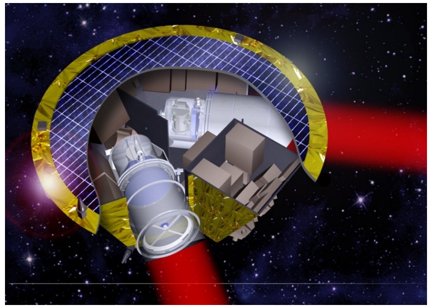
Current research activities:

- Drag-Free GNC algorithms for gravity/science missions.
- Attitude control of under-actuated spacecraft.
- MPC-based Guidance and control systems in autonomous missions/maneuvers.
- Trajectory design and control for landing maneuvers.
- Quantum optimization for space mission planning.

Drag-Free GNC algorithms for gravity/science missions

LISA drag-free and attitude control system design (ESA project, collaboration with Thales Alenia Space).



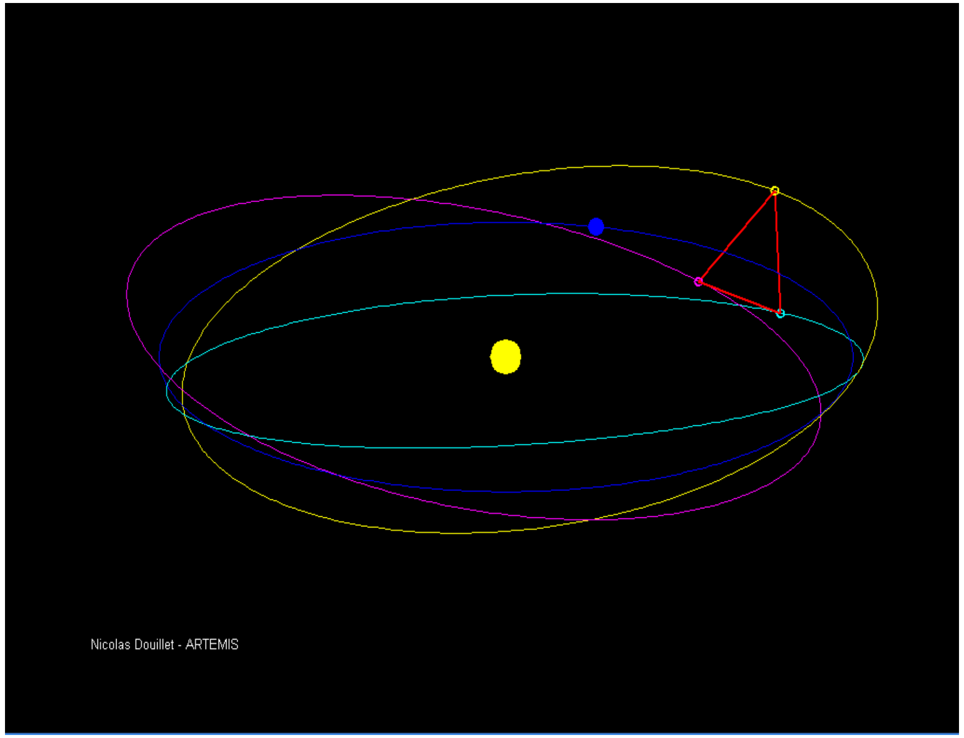


Objectives

- The mission goal is to detect/study gravity waves generated by astronomical events.
- The project goal is to develop a drag-free and attitude control system for the science phase of the LISA mission.
- Drag-free is fundamental to have the test masses in free fall conditions.

Activities

- Modelling of the LISA multibody dynamics, linearization and decoupling.
- H_∞ control for the attenuation of disturbances and noises.
- Requirements feasibility, robust stability and robust performance analysis.
- Monte Carlo simulation campaign.



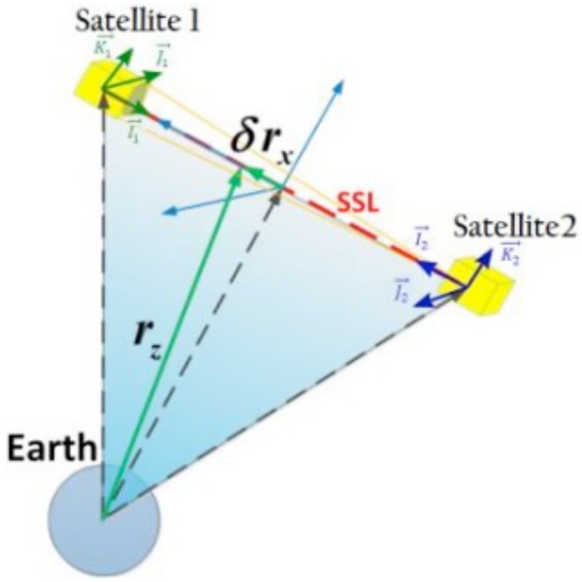
Drag-Free GNC algorithms for gravity/science missions

NGGM drag-free, formation and attitude control (ESA project, collaboration with Thales Alenia Space).

Objectives: GNC system design for **long-term monitoring of the temporal variations of Earth's gravity field** at high resolution in time (down to 3 days) and space (100 km).

- Information about mass exchange among atmosphere, oceans, cryosphere and land → picture of the Global Change.
- NGGM will give continuity with respect to predecessor missions like GRACE, GOCE and GRACE-FO.
- The mission will be complementary to other Earth Observation, like the ESA Earth Explorer and Copernicus.

Activities: **Drag-free, formation and attitude control** system has been designed and tested using simplified and high-fidelity simulators.

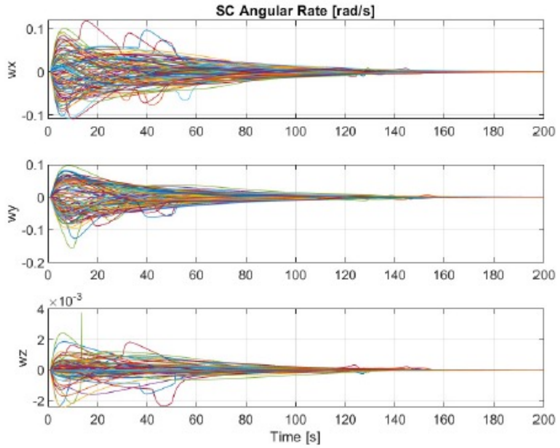


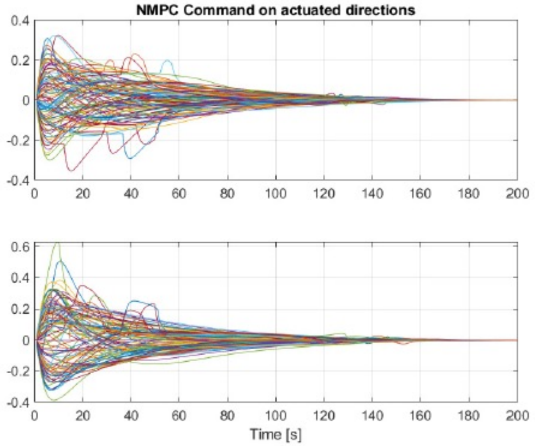
Attitude control of under-actuated spacecraft.

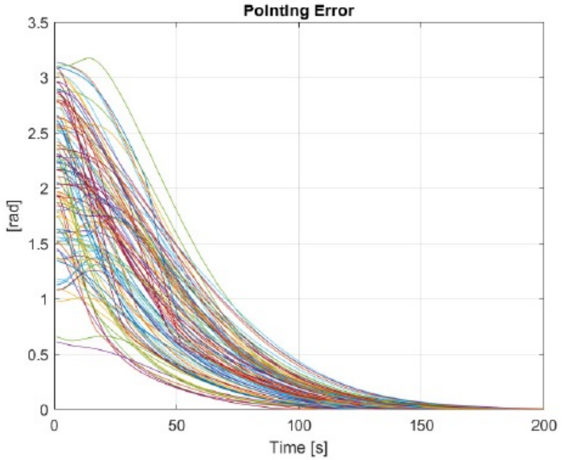
Attitude Control for underactuated systems (Polito research activity)

- The interest in attitude control laws for underactuated spacecraft is motivated by the possibility of adopting magnetic actuators for attitude control and/or maintaining an acceptable level of operability after failure of a non-redundant attitude control systems.

- MPC approach is able to handle the issue of large angle slew maneuvers as well as stabilization of a prescribed attitude in the presence of model uncertainties and, possibly, external perturbations, by means of a cluster of only two reaction wheels.







MPC-based Guidance and control systems in autonomous missions/maneuvers.

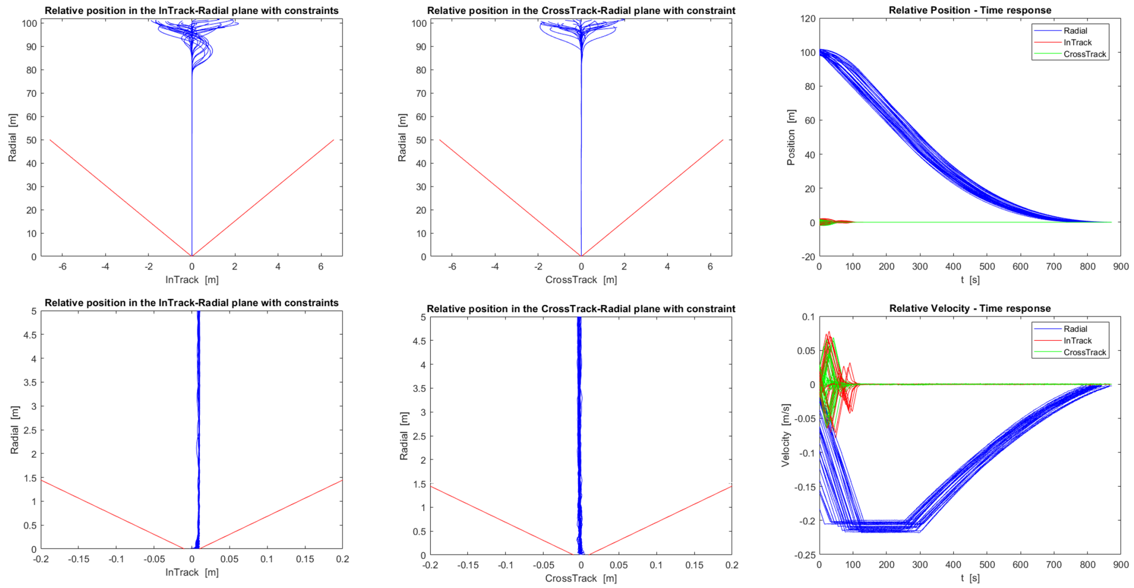
SROC, Space Rider Observer Cube (ESA/ASI project)

- SROC is an ESA technology featuring a CubeSat that is deployed from the Space Rider, performs an inspection phase, and rendezvous and docking with a dedicated retrieval mechanism hosted in the Space Rider cargo bay.

- Activities:

  - CubeSat **navigation filter design** (different types of Kalman filter).

  - **MPC design** for CubeSat guidance and control.



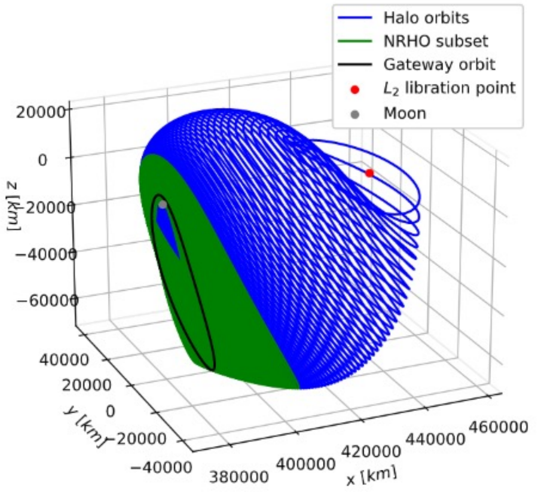
MPC-based Guidance and control systems in autonomous missions/maneuvers.

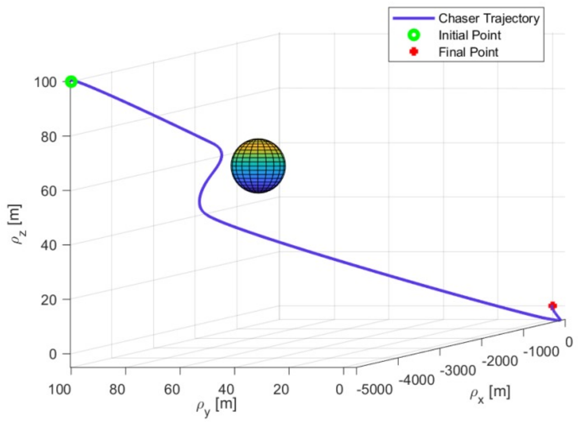
Space rendezvous in Halo/Lunar Orbit (Polito research activity)

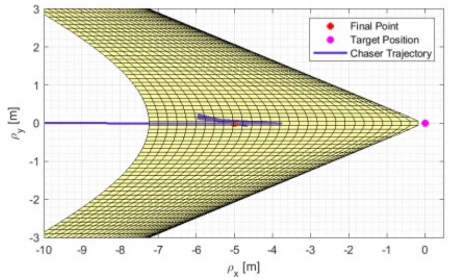
- The satellite dynamics is described by the Circular Restricted 3-body problem equations of motion.
- Nonlinear Model Predictive Control technique is applied to a realistic test case since the target orbit was selected to be the same as the Lunar Gateway (mission Artemis IV) .
- Set of nonlinear/non-convex constraints are accounted for the rendezvous maneuver:

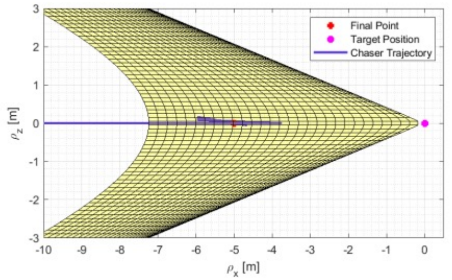
The SC is required to lie within the exterior of the sphere - a non-convex set - in order to verify the capability of the SC in autonomous collision avoidance.

The SC is constrained into the interior of a cone, i.e. the classical case of the conic line-of-sight constraint. This allows the SC to keep the line-of-sight contact with docking port of the target and/or to approach the target along the proper direction.









MPC-based Guidance and control systems in autonomous missions/maneuvers.

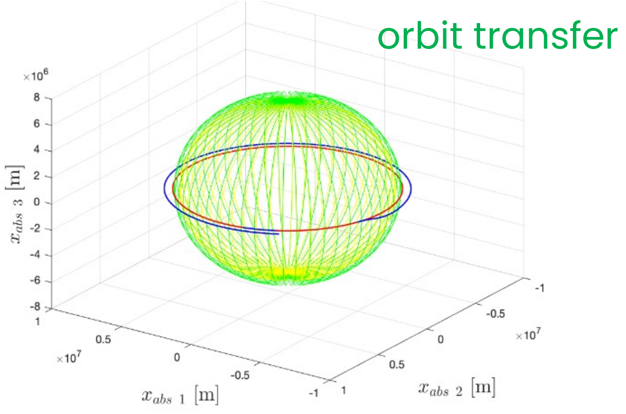
Space debris removal (Polito research activity)

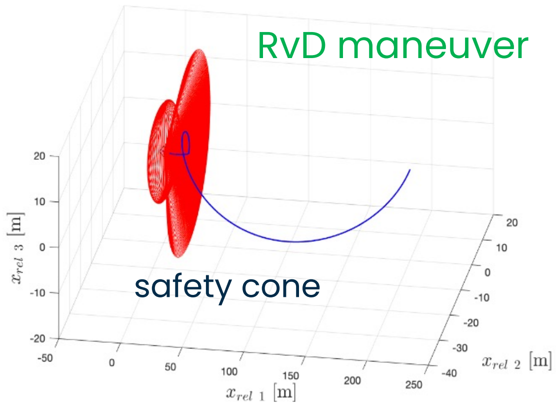
Space debris orbiting around the Earth is becoming a major problem that could compromise the future of space exploration.

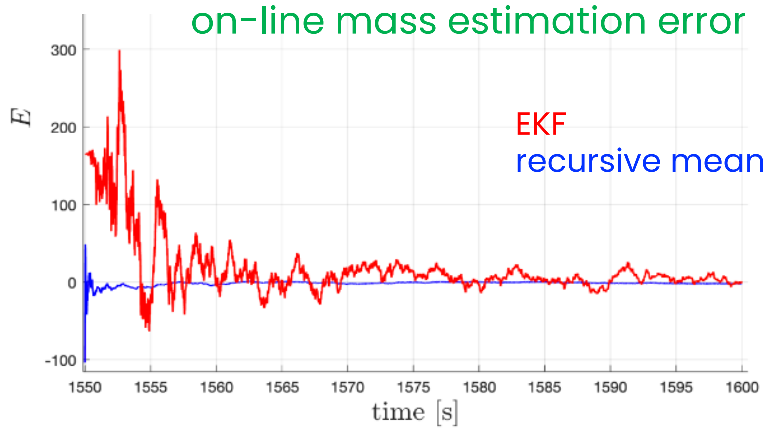
Overall mission:

- S/C rendezvous and docking (RvD) with the debris
- Estimation of the debris parameters (e.g., mass, inertia matrix)
- Transfer to a parking orbit.

A NMPC control system has been designed to perform this mission.



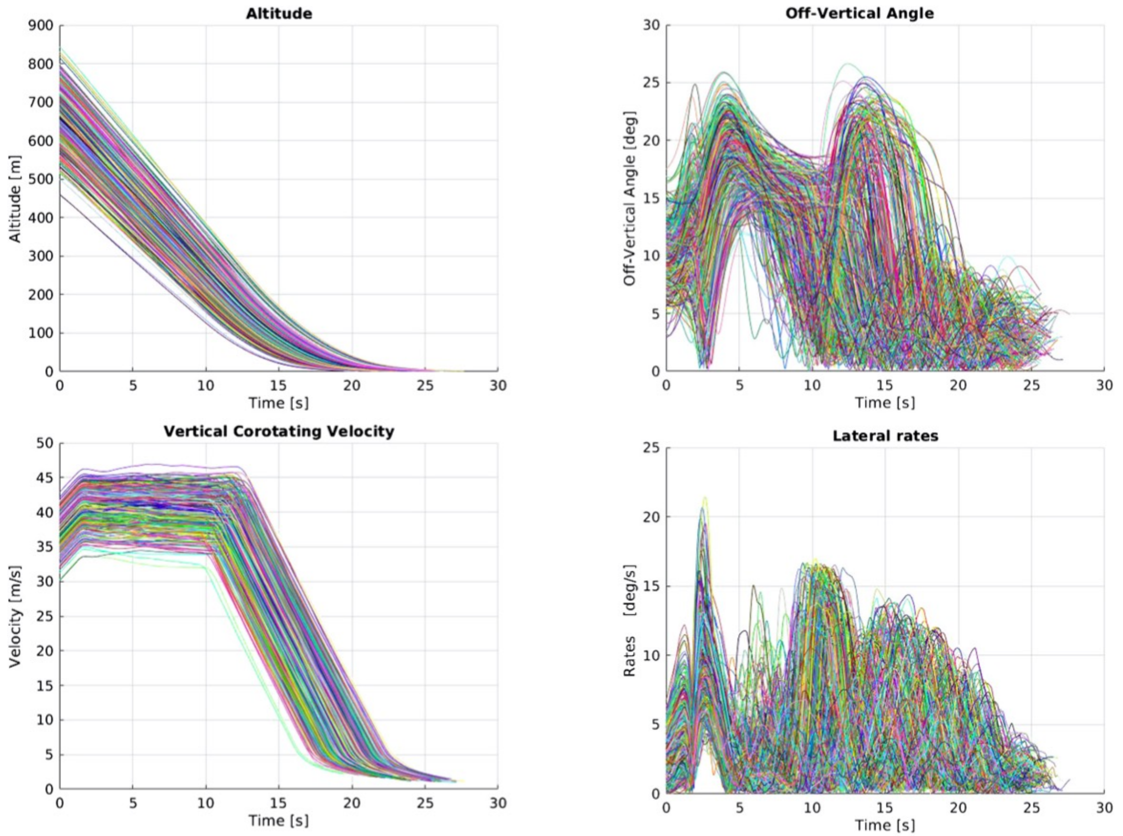




Trajectory design and control for landing maneuvers

ExoMars landing robustness verification (ESA project, collaboration with TAS)

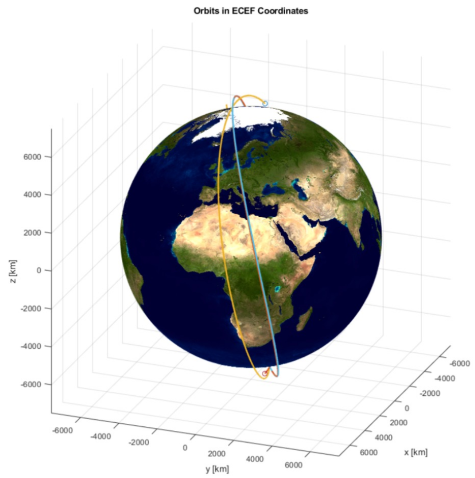
- Design of landing GNC is one of the most challenging and complex tasks: need to ensure stability of the lander motion with a certain level of robustness.
- A novel procedure for the verification of the lander nominal and robust stability has been developed:
  1. Model simplification → reduce degrees of freedom and allow a decoupled analysis.
  2. Analytical robustness stability verification is performed via µ-Analysis.
  3. Monte Carlo campaign, using an End-to-End simulator in order to verify, in the time domain, the reliability of the analytical stability analysis.
- The procedure has been applied to the case of the Exomars mission.

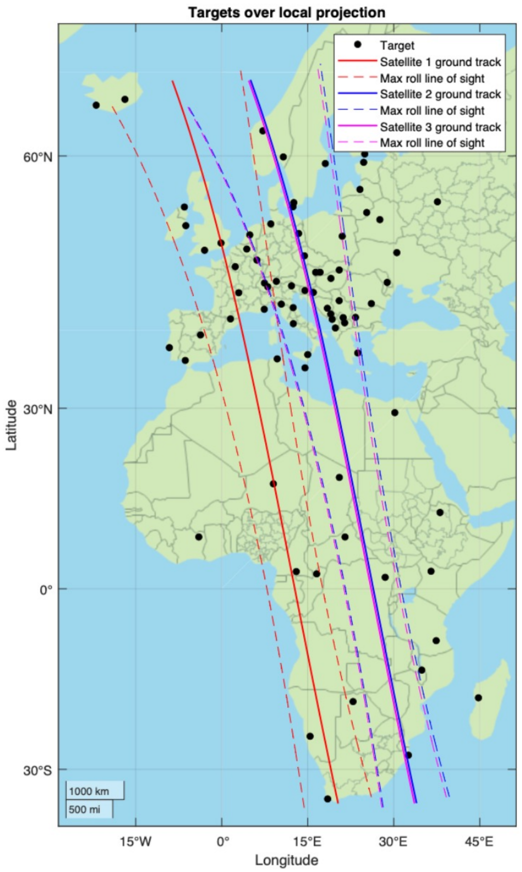


Quantum optimization for space mission planning

Quantum optimization - Scheduling for a constellation of agile earth observation satellites (Polito research activity)

- Constellation of several satellites traveling on different orbits.
- The orbits are designed in such a way that an arc of each orbit lies above a given region of the Earth containing targets of interest.
- The satellites have to acquire observations/images from the targets.
- The goal is to find an optimal observation scheduling for the satellites of the constellation:
  - Maximize the profit (number of acquired targets weighted with given priorities).
  - Each target acquired only once.
  - Satisfy physical constraints (e.g., the observation of two consecutive targets may be not feasible).
  - Minimize energy consumption.

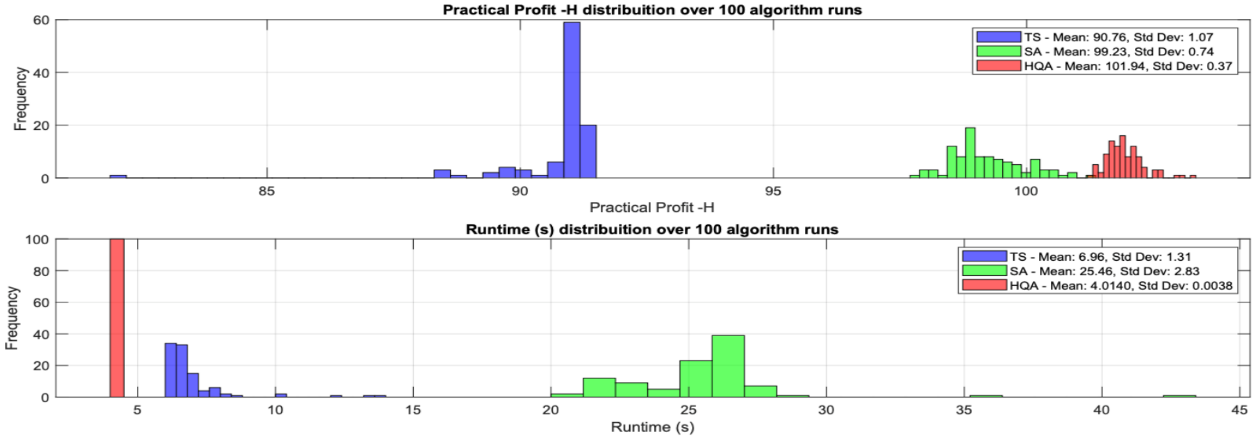


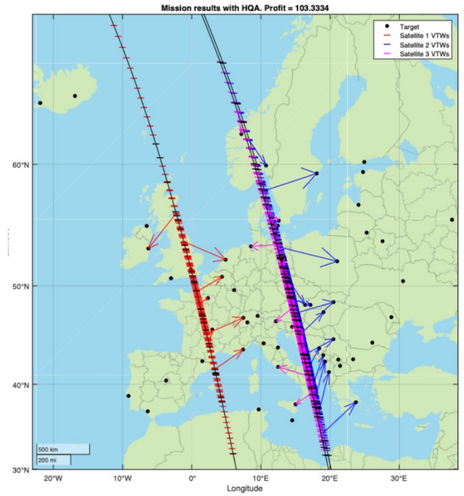


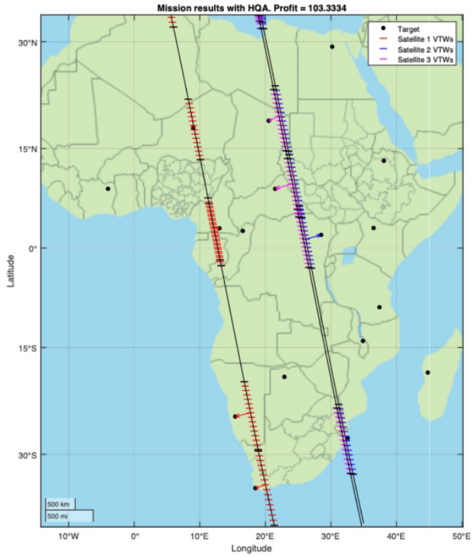
Quantum optimization for space mission planning

Quantum optimization - Scheduling for a constellation of agile earth observation satellites (Polito research activity)

- Quantum Annealers (QAs), have the potential to significantly reduce the computational complexity of these classes of problems, allowing their solution with a polynomial speedup with respect to classical computers, providing at the same time better solutions.
- The results are shown in the figures, comparing the following optimization approaches:
  - Hybrid Quantum Annealing (HQA) running on a real QA provided by D-Wave.
  - Simulated Annealing (SA) - classical algorithm used for this class of problems.
  - Tabu Search (TS) - classical algorithm used for this class of problems.







Thank you!

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