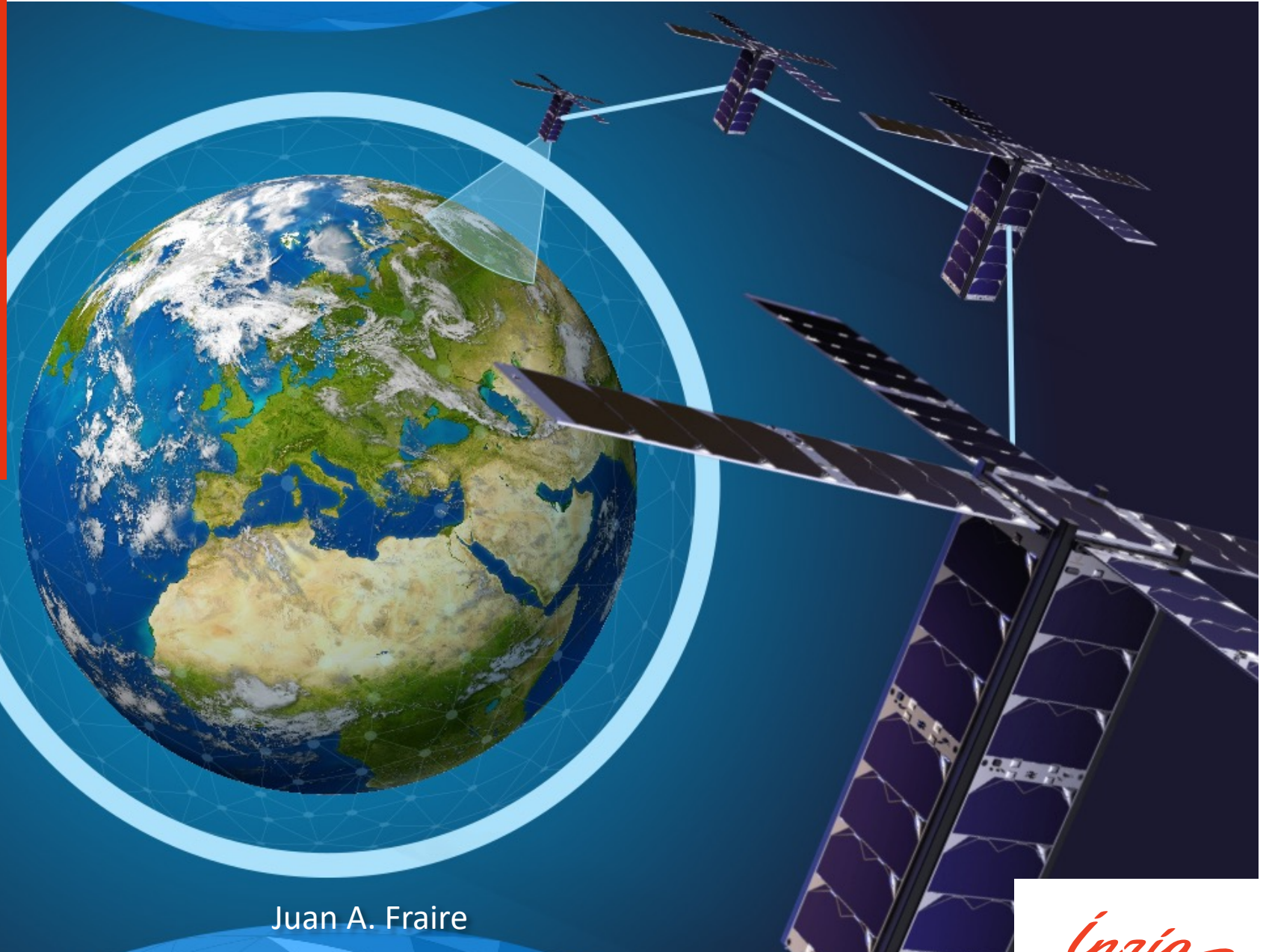


Inria

**Space-Terrestrial
Integrated IoT**
Challenges and Opportunities

Journées non thématiques
GDR RSD
Lyon, 2023



Juan A. Fraire

Only
of the world's surface has
terrestrial connectivity

10%

Space-Terrestrial
Integrated IoT
STEREO



Space-Terrestrial
Integration



Bidirectional
Communication



Dense/Sparse
Constellations



Low-cost
Connectivity



Agriculture



Utilities



Tracking

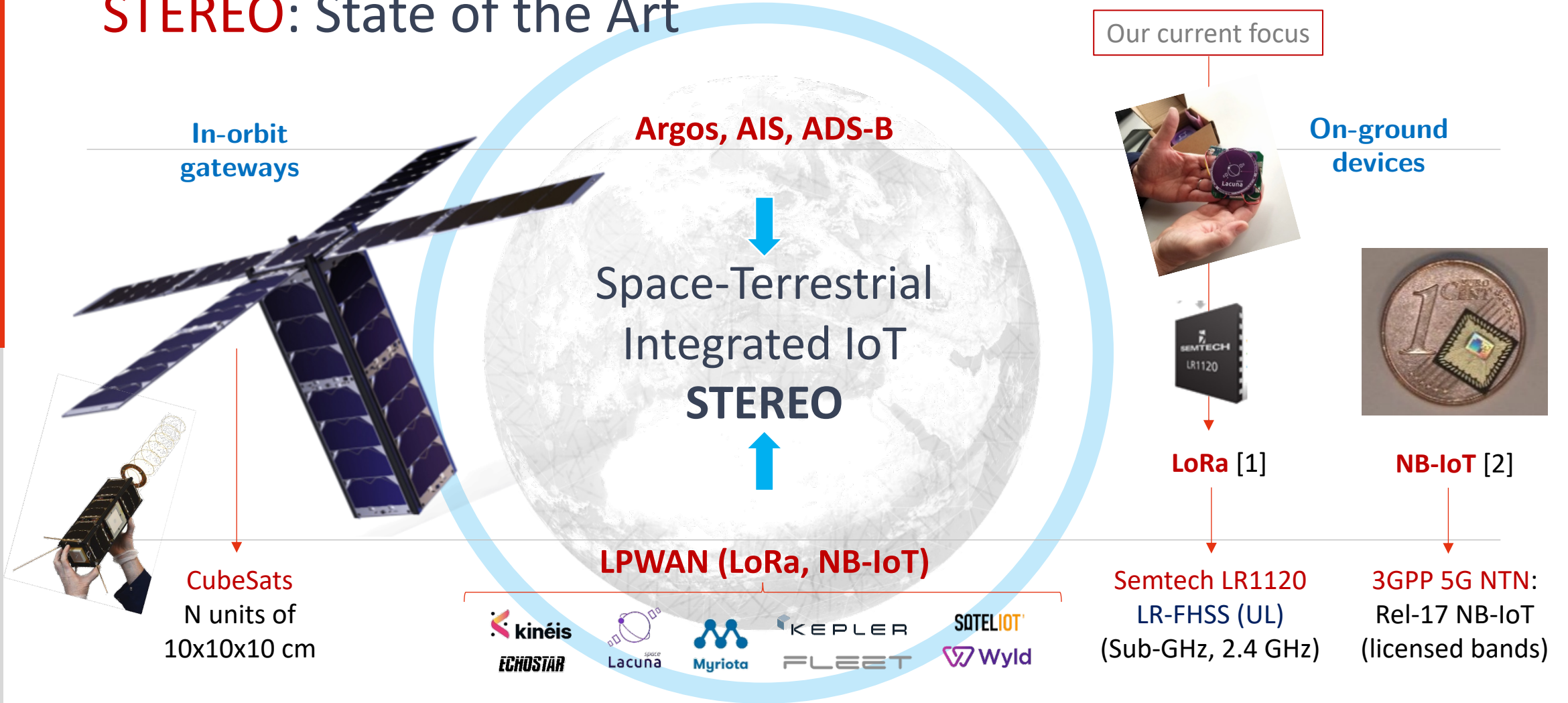


Maritime



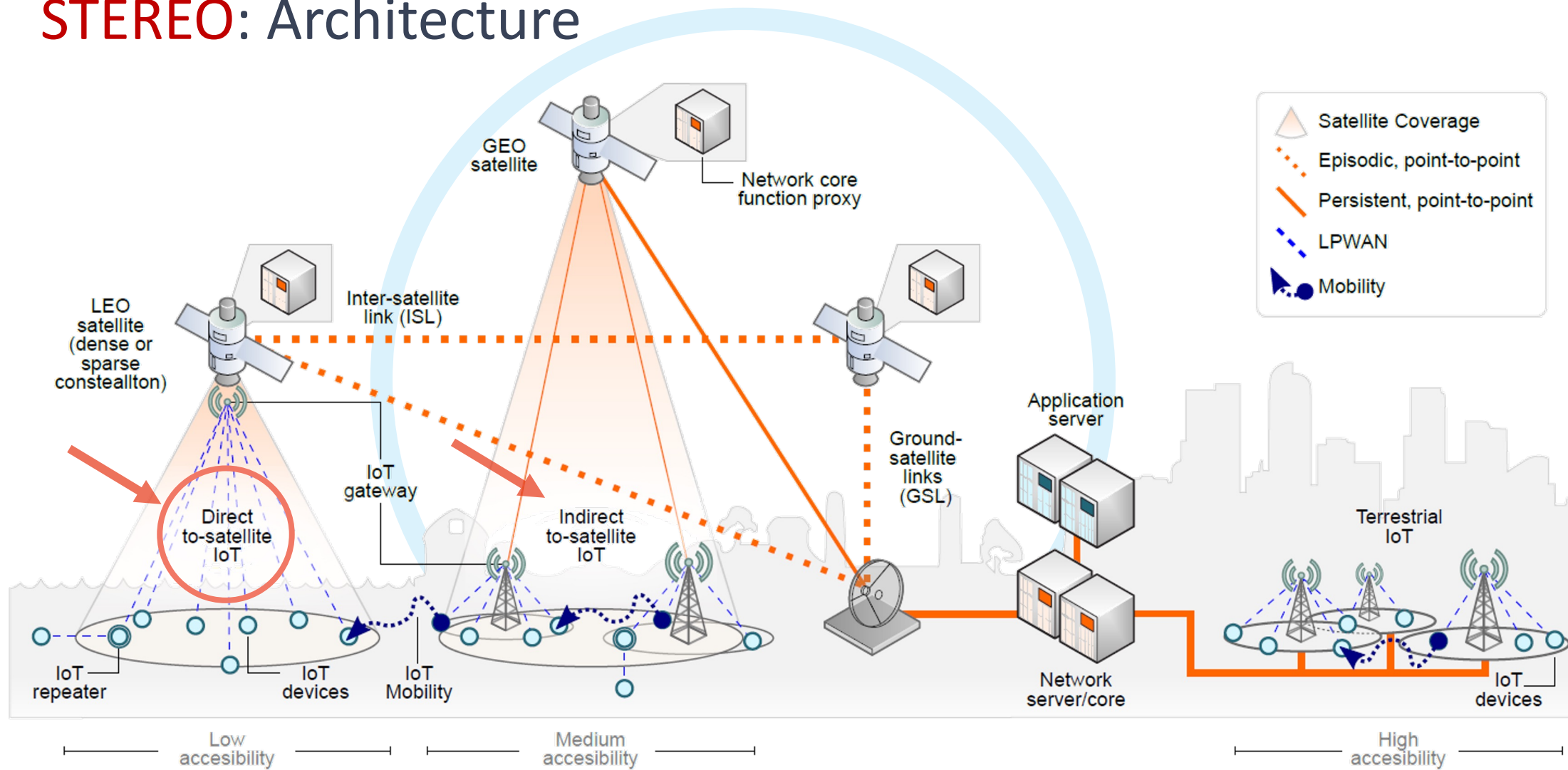
Logistics

STEREO: State of the Art



[1] N. Sornin (Semtech), Extending LoRaWAN Reach (https://youtu.be/pHq7_rgDyFA); Thomas Telkamp (Lacuna) Open satellite LoRaWAN at scale (<https://youtu.be/vWkuqVJL1Sg>)
[2] L. Ouvry, et al, "An Ultra-Low-Power 4.7mA-Rx 22.4mA-Tx Transceiver Circuit in 65-nm CMOS for M2M Satellite Coms," in IEEE Transactions on Circuits and Systems, May 2018

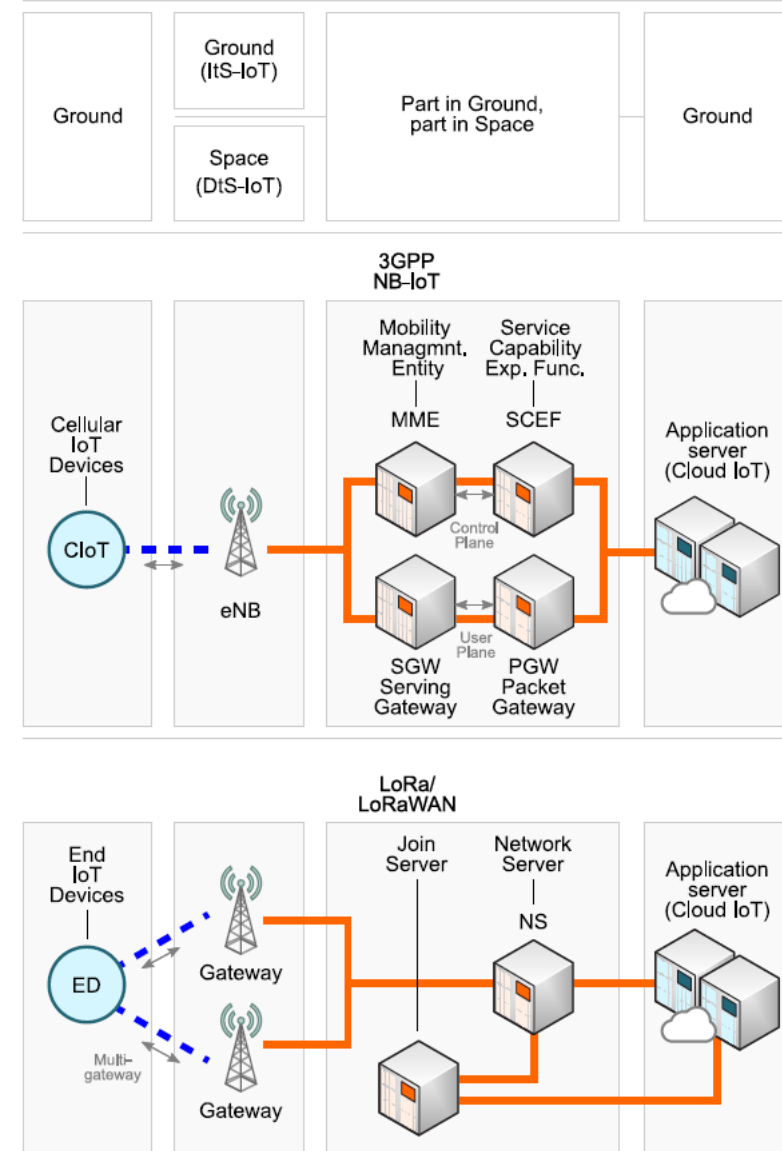
STEREO: Architecture



STEREO: Open Challenges

- **Architecture Adaptations**
 - Radio-Access - spectrum and protocols
 - Core-Network - opportunistic contacts
- **Software and Hardware**
 - Synchronization & Localization - orbital info
 - Mobility & Routing - roaming
 - Transmission & Reception Policies
 - Function Virtualization & Localization →
- **Management and Operations**
 - Design & Operation - culture clash
 - Performance Evaluation

■ ■ STEREO ANR: Inria, LIG, IRIT, LAAS, Kineis



STEREO: On-Going Efforts

MISSION (EU RISE), STARS (SticAmSud) 2021-2022

- **Architecture Adaptations**
 - Radio-Access - spectrum and protocols
 - Core-Network - opportunistic contacts
- **Software and Hardware**
 - Synchronization & Localization - orbital info
 - Mobility & Routing - roaming
 - Transmission & Reception Policies
 - Function Virtualization & Localization
- **Management and Operations**
 - Design & Operation - culture clash
 - Performance Evaluation

STEREO ANR: Inria, LIG, IRIT, LAAS, Kineis

Space-Terrestrial Integrated Internet of Things: Challenges and Opportunities
 Juan A. Fraire, Oana Iova, and Fabrice Valois

RESS-IoT: A Scalable Energy-Efficient MAC Protocol for Direct-to-Satellite IoT
 RAYDEL ORTIGUEIRA, JUAN A. FRAIRE, TOMÁS FERRER, AND SANDRA CÉSPEDES

Distributed On-Demand Routing for LEO Mega-Constellations: A Starlink Case Study
 Gregory Stock, Juan A. Fraire, Holger Hermanns

Uplink Transmission Policies for LoRa-Based Direct-to-Satellite IoT
 GUIDO ALVAREZ, JUAN A. FRAIRE, AND DIRK PESCH

Uplink Transmission Probability Functions for LoRa-Based Direct-to-Satellite IoT: A Case Study
 Kai Vogelsang, Juan A. Fraire, Holger Hermanns

Simulating LoRa-Based Direct-to-Satellite IoT Networks with FLORASAT
 Juan A. Fraire, Pablo Madory, Mehdi Ali Mesbah, Oana Iova, Fabrice Valois

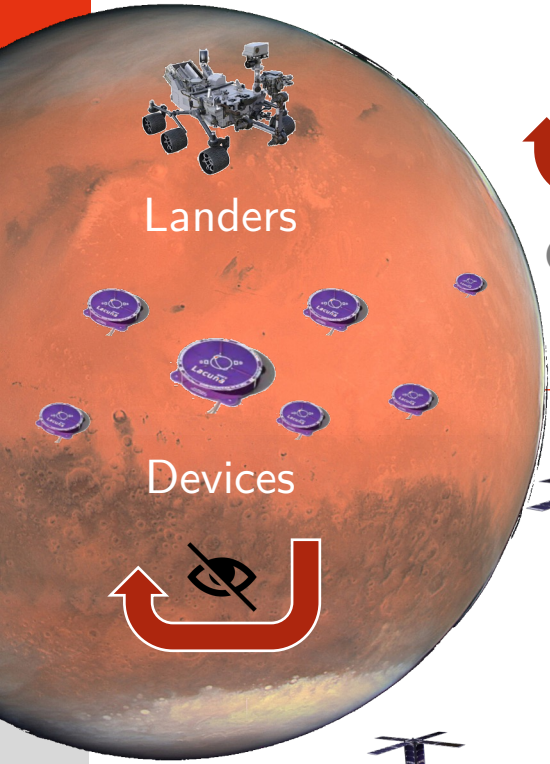
Network Size Estimation for Direct-to-Satellite IoT
 Pablo Habac, Samuel Montejo-Sánchez, Richard Demo Souza

Sparse Satellite Constellation Design for Global and Regional Direct-to-Satellite IoT Services
 Gabriel Malosini Capes, Santiago Hemo, Juan A. Fraire, Roberto Gastello

+ LR-FHSS + Analytical tput models + DTN topics

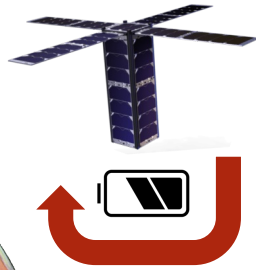
STEREO: Towards Deep Space

NASA's DSN



Landers

Devices



CubeSats



GEO: ~40,000km
Mars: ~400,000,000km

Signal 100 million times weaker

min 3.1 min
avg **12.5 min** *owl*
max 22.4 min

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
AU	0,38	0.72	1.00	1.52	5.21	9.54	19.18	30.11
	3 min	6 min	8 min	12 min	43 min	1h20	2h40	4h10

New space exploration concepts



Thank you!

juan.fraire@inria.fr