Space-Aviation Interface
Very High-Speed Operations

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Space-Aviation Interface
Very High-Speed Operations
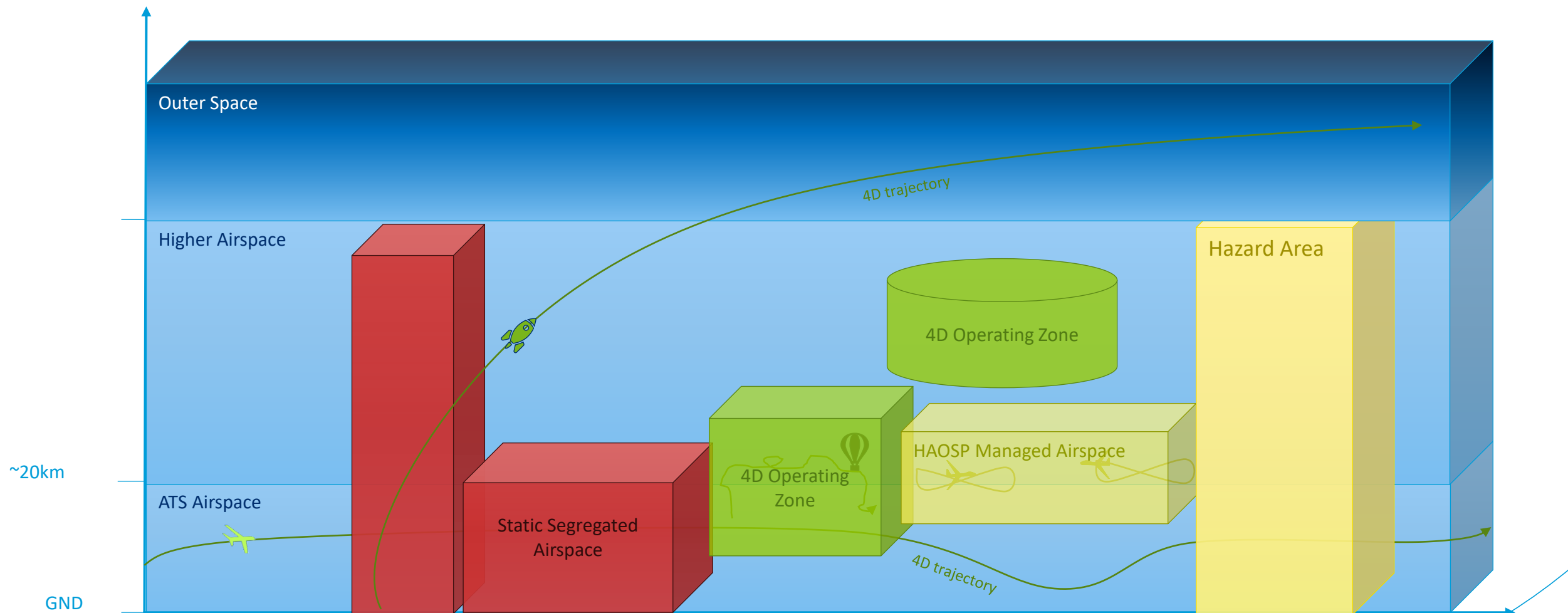
Concept elements
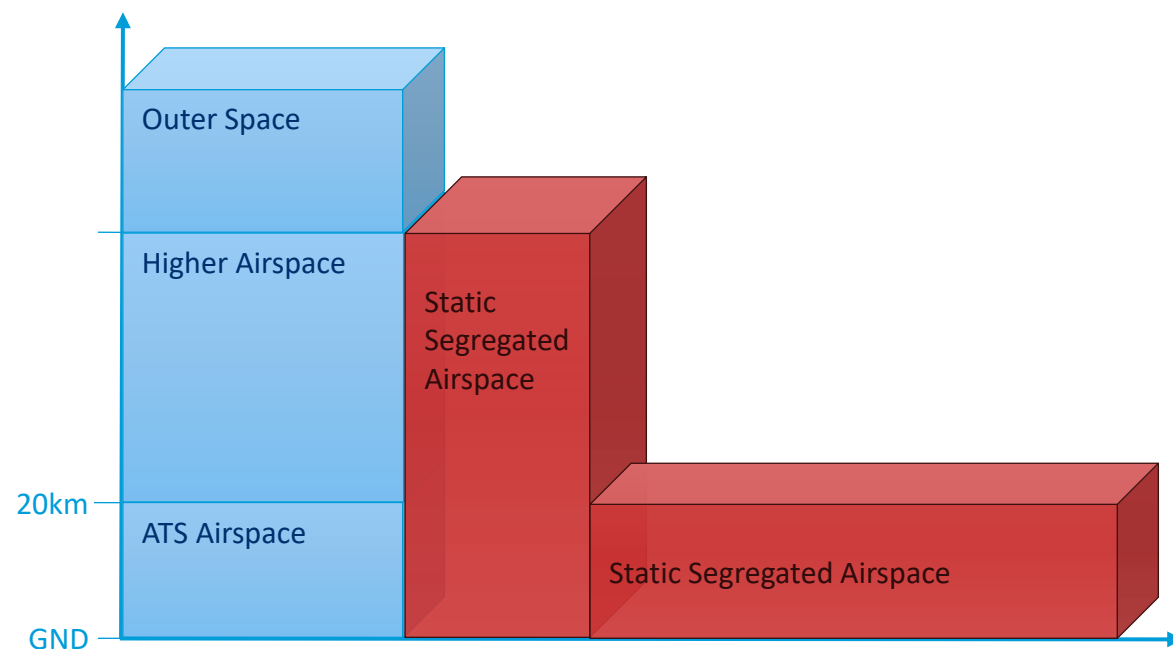
Roles and Actors

Space-Aviation Interface

Very-high speed examples

- Vertical launch
- Air-launch
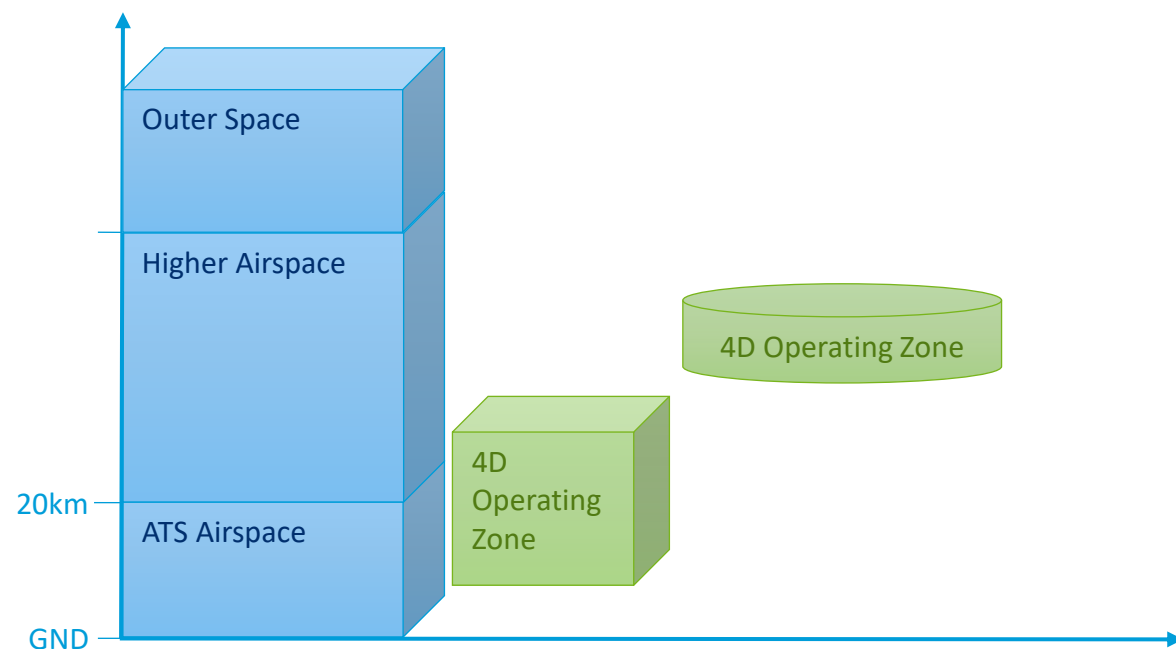- Re-entry / From orbit
- A to A
- A to B

Concept Elements

Restricted Airspace

- Vehicle authorisation may require efficient segregation procedure
- Segregated areas along a flight trajectory for which sufficient levels of safety cannot be assured by other means

Outer Space

Higher Airspace

Static Segregated Airspace

20km

ATS Airspace

Static Segregated Airspace

GND

4D Operating Zone

- Vehicle-centric area with defined lateral/vertical dimensions

- A 4D volume of airspace moving alongside a trajectory profile

- Allocated to one or several specific vehicles

- Ensures vehicle separation from other (higher) airspace users

- Considers level of uncertainty for type of operation.

4D Operating Zone – Interaction and reconfiguration

- Locations and volumes of 4D operating zones can change over time

- Adaptation to needs and flight intents of different airspace users
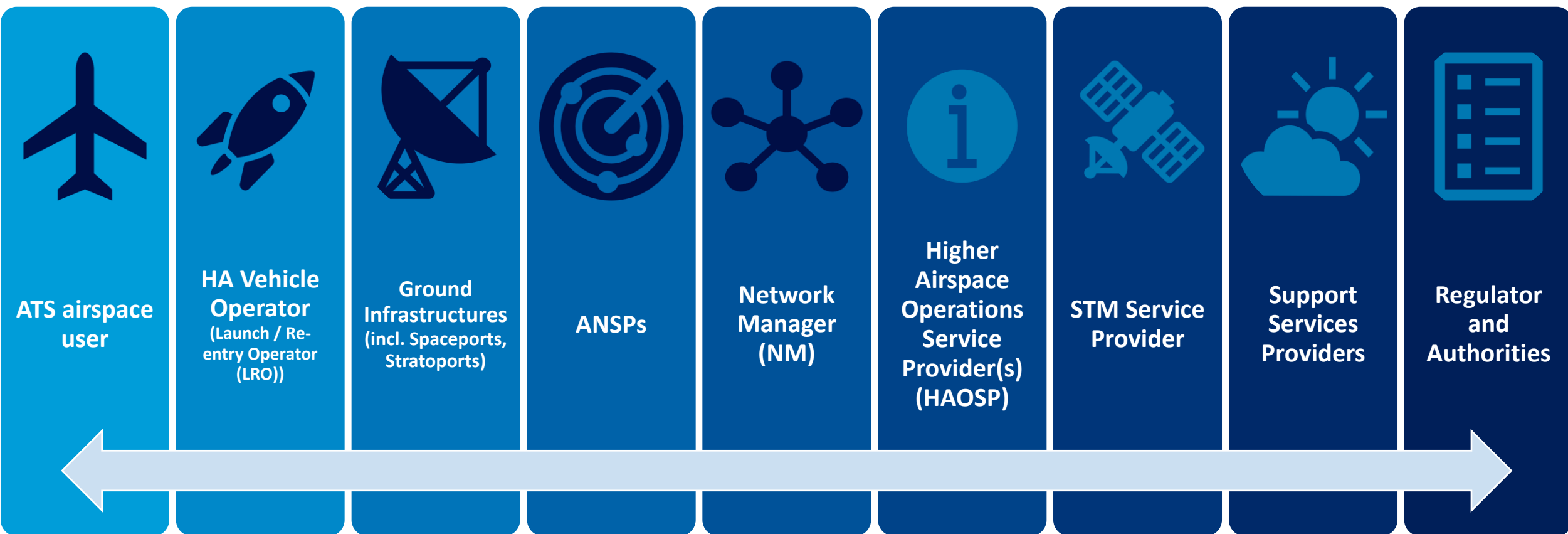
HAOSP Managed Airspace
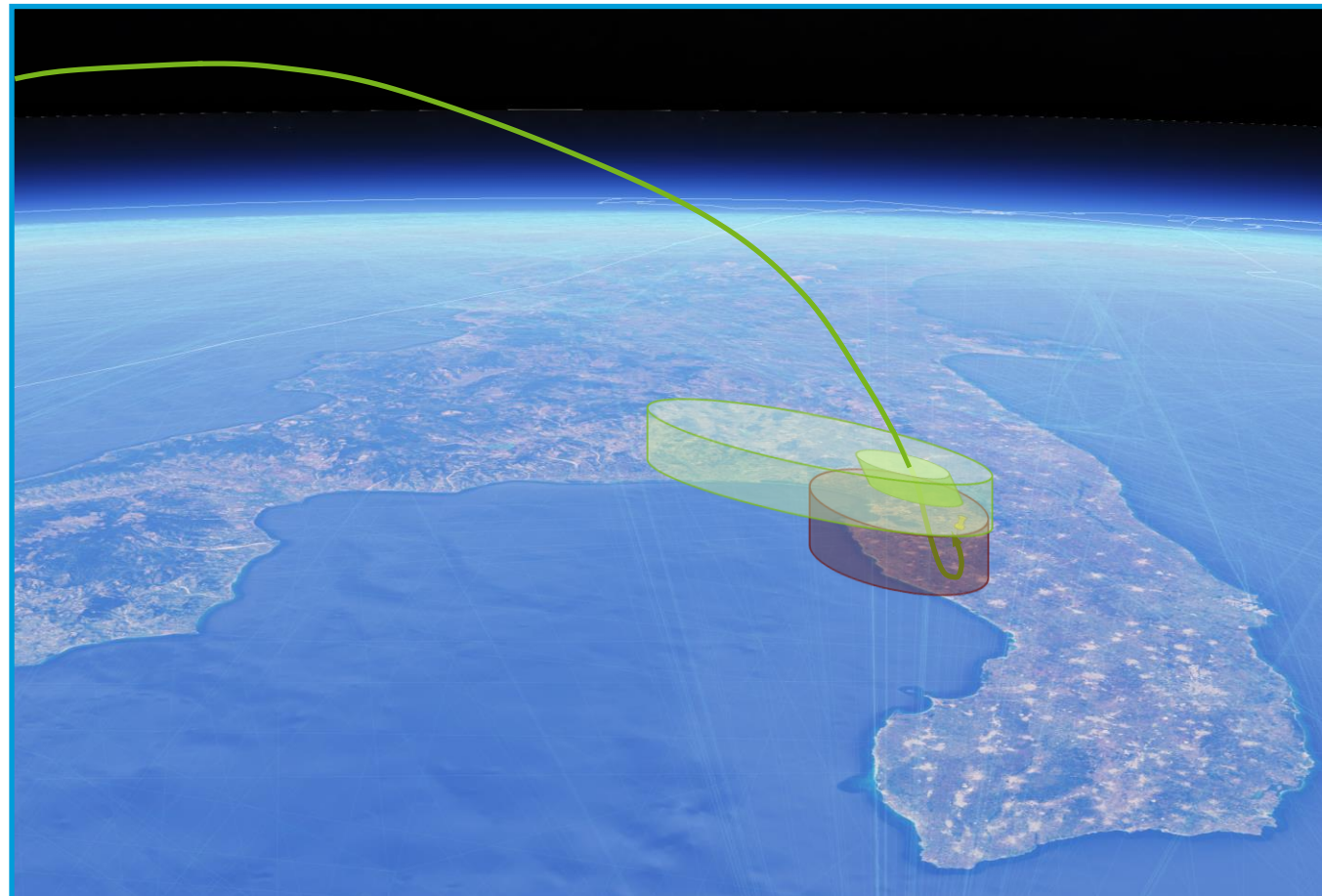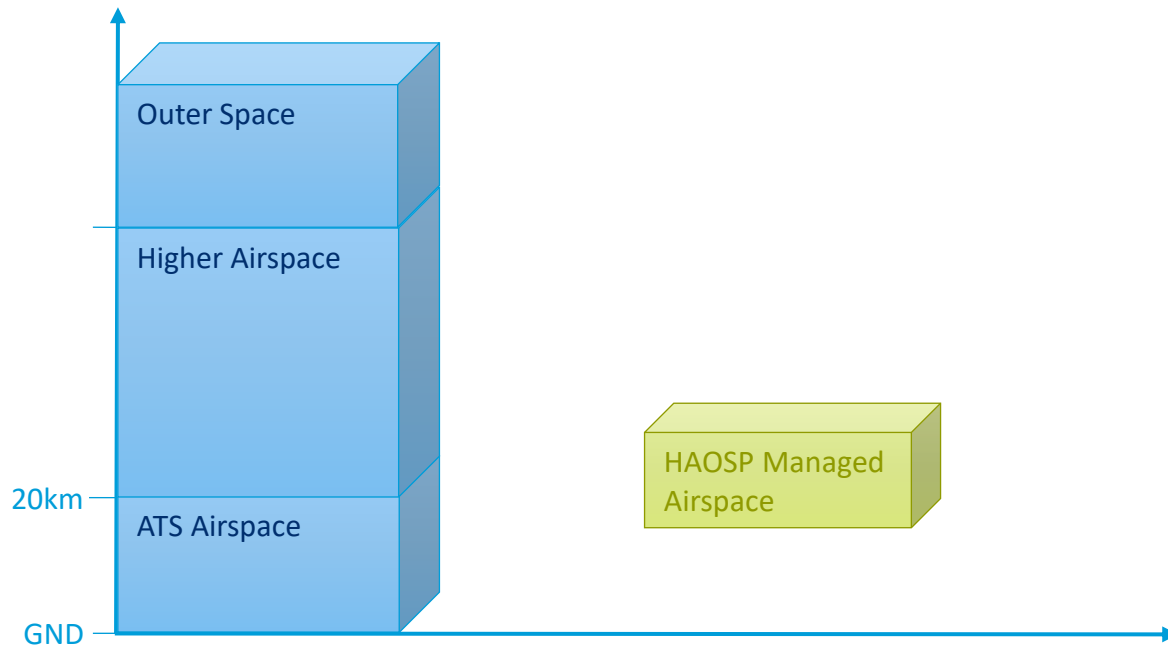
- Strategic de-confliction may not be possible through out flight execution
- Tactical traffic information and monitoring is required
- Higher-Airspace Operation Service Provider (HAOSP)
  - support operators in their separation provision task, and/or
  - provide separation service for HA users unable to do for themselves

Aircraft Hazard Area (AHA)

Outer Space

Higher Airspace

20km

ATS Airspace

GND

Hazard Area
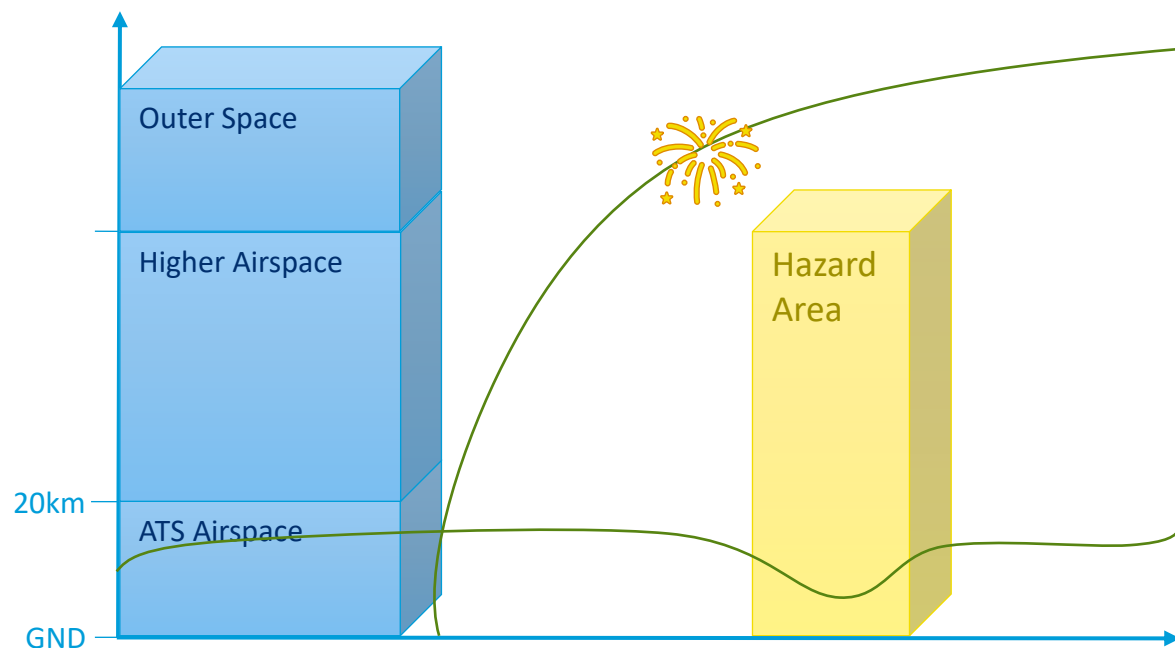
- Airspace regions endangered by non-nominal situations, which can be cleared of other airspace users on time to prevent any collision with resulting debris

- Dynamic AHA require real-time monitoring and data-processing capabilities

- Dynamic AHA complements use of 4D operating zones and DMAs
  - separation of vehicle operational volume

Roles / Actors (Target Concept)

ATS airspace user

HA Vehicle Operator (Launch / Re-entry Operator (LRO))

Ground Infrastructures (incl. Spaceports, Stratoports)

ANSPs

Network Manager (NM)

Higher Airspace Operations Service Provider(s) (HAOSP)

STM Service Provider

Support Services Providers

Regulator and Authorities

Space-aviation Interface

Planning phase

- Coordination of intended trajectory, applying strategic deconfliction
  - **ATS airspace** coordination via CDM together with NM
  - **HA coordination** via CDM together with NM
  - **Space** operation related coordination via STM service provider
- Mission requirements ←→ impact on other traffic
  - as little impact as possible for other users & European network
- Potential **non-nominal behaviour** taken into account in planning
  - evaluated at both regimes → ensuring required safety margins

Mission requirements

Coordination and Reconciliation

Impact of operations on other traffic

Space-aviation Interface

Execution phase

- **Deviations** from planned trajectory
  - to be checked for impact in both domains
  - measures initiated through processes in **ATM and STM**
- **STM service providers** maintain situational awareness and support the vehicle operator through means of SSA.
- **Prioritised execution** required after specific flight events have been initiated (e.g. rocket ignition, re-entry burn)

Space-aviation Interface

Contingency management

→ Short term

- Based on existing methods and procedures
- HAO planned well in advance
- Strategic measures ensure safety in the event of an incident
  - Flight plan or reserved airspace at launch / re-entry site (segregated airspace)

Management of **non-nominal events** through **coordination at network level**, adressed as part of **CDM process** with agreement of **all actors.**
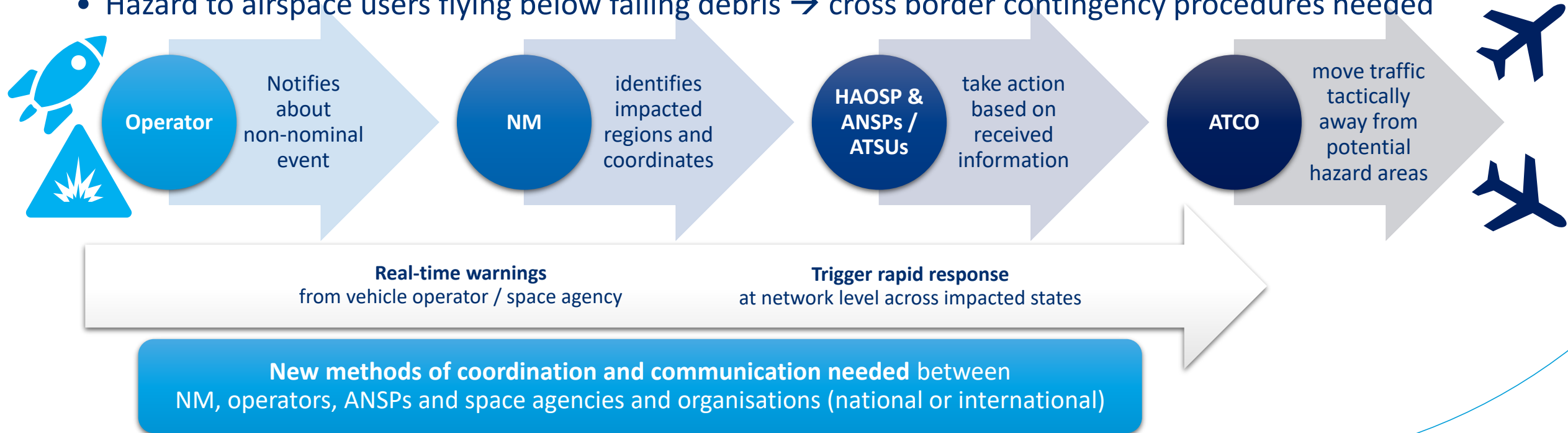
Contingencies of High-speed vehicles

- Fragmentation/catastrophic failure
- Loss of flight performance
- Impaired vehicle controls
- Unknown or degraded knowledge of vehicle status
- Loss of communications link between vehicle and launch operator or ATC
- Transponder failure/telemetry failure
- Diversion from the nominal trajectory
- Uncontrolled descent
- Unwanted or early capsule release
- Uncontrolled re-entry
- Need for assistance to land in an alternate site or landing out of nominal conditions

Space-aviation Interface

Contingency management
→ Medium-to-long term (Target Concept)

- High-speed vehicles: time is critical factor: event over one State → impact may be far reaching
- Hazard to airspace users flying below falling debris → cross border contingency procedures needed

Operator — Notifies about non-nominal event

NM — identifies impacted regions and coordinates

HAOSP & ANSPs / ATSUs — take action based on received information

ATCO — move traffic tactically away from potential hazard areas

Real-time warnings from vehicle operator / space agency

Trigger rapid response at network level across impacted states

New methods of coordination and communication needed between NM, operators, ANSPs and space agencies and organisations (national or international)

Very-high speed examples

Launchers

Texus sounding rocket (Esrange, Sweden)

PLD Miura 1 sounding rocket

Virgin Orbital Launcher One

SpaceX F9 Heavy booster recovery
(not envisaged from Europe)

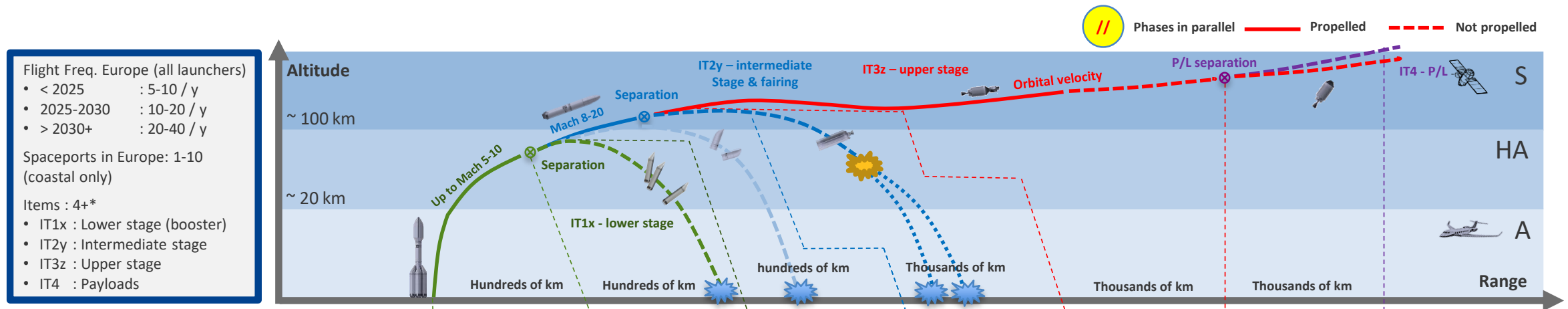Reaction Engines Skylon SSTO
Rocketplane concept

Zero2infinity Bloostar concept

A to A
- Vertical Rocket
- Air Launch Rocket
- ...tP...

...B
- ...so...
- ...so...
- ...so... (...zontal L.)
- Hypersonic Spacecraft (Vertical L.)

Launcher
- **Sounding rocket**
- **Direct Launch Expendable Rocket w/o de-orbit**
- **Direct Launch Expendable Rocket with de-orbit**
- **Direct Launch Semi Reusable Rocket**
- **Direct Launch Reusable Rocket**
- **Air Launch Expendable Rocket**
- **RocketPlane**

From Orbit
- Re-entry vehicle
- Satellite de-orbit

Flight Freq. Europe (all launchers)
- < 2025 : 5-10 / y
- 2025-2030 : 10-20 / y
- > 2030+ : 20-40 / y

Spaceports in Europe: 1-10 (coastal only)

Items : 4+*
- IT1x : Lower stage (booster)
- IT2y : Intermediate stage
- IT3z : Upper stage
- IT4 : Payloads

// Phases in parallel — Propelled --- Not propelled

Altitude

~ 100 km

~ 20 km

Separation
Mach 8-20
Up to Mach 5-10
Separation

IT2y – intermediate Stage & fairing

IT3z – upper stage
Orbital velocity

P/L separation
IT4 - P/L

IT1x - lower stage

Hundreds of km   Hundreds of km   hundreds of km   Thousands of km   Thousands of km   Thousands of km

S

HA

A

Range

today

Time and airspace segregation

Trajectories monitoring

Vertical launch to orbit

Planning phase:

LRO:
- Develops and shares mission trajectory and associated airspace volumes
- Requests restricted airspace,
- Provides mission plan and event chronology
- Considers related contingecy hazard areas

NM, ANSP, HAOSP, STM together with LRO
- Check and coordinate to solve potential strategic conflicts
- Coordinate entry/exit points with STM
- Trajectory / airspace volume optimized (including non-nominal events) through CDM

- Submits NOTAM notifying on airspace restrcitions

Google Earth

Vertical launch to orbit

Execution phase:

LRO:
- Checks weather / space weather prior launch
- Activates airspace restrictions in ATS airspace
- Activates entry into HAO airspace
- Monitors vehicle, informs ATM, HAOSP and STM on trajectory updates
- Initiate release of airspace restcion when area is clear

NM
- Monitors conditions of operation (no emergencies ongoing)

ANSP
- Ensures safe operation around restricted airspace

HAOSP
- Monitors vehicle position when in HA, ensures separation between 4D operating zone and other HA traffic

ECHO

Google Earth

Vertical launch to orbit

Non-nominal event:

LRO:
- Informs NM in real time

Refined Hazard area (RHA) will be calculated based on last vehicle state vector

NM:
- Determins the affected ANSP/ATSU based on RHA

ANSP:
- Receives notification from NM, triggers contingency procedures
- ATCO reactively moves traffic away from RHA

HAOSP
- Monitors entry parameters and ensures safe separation provision
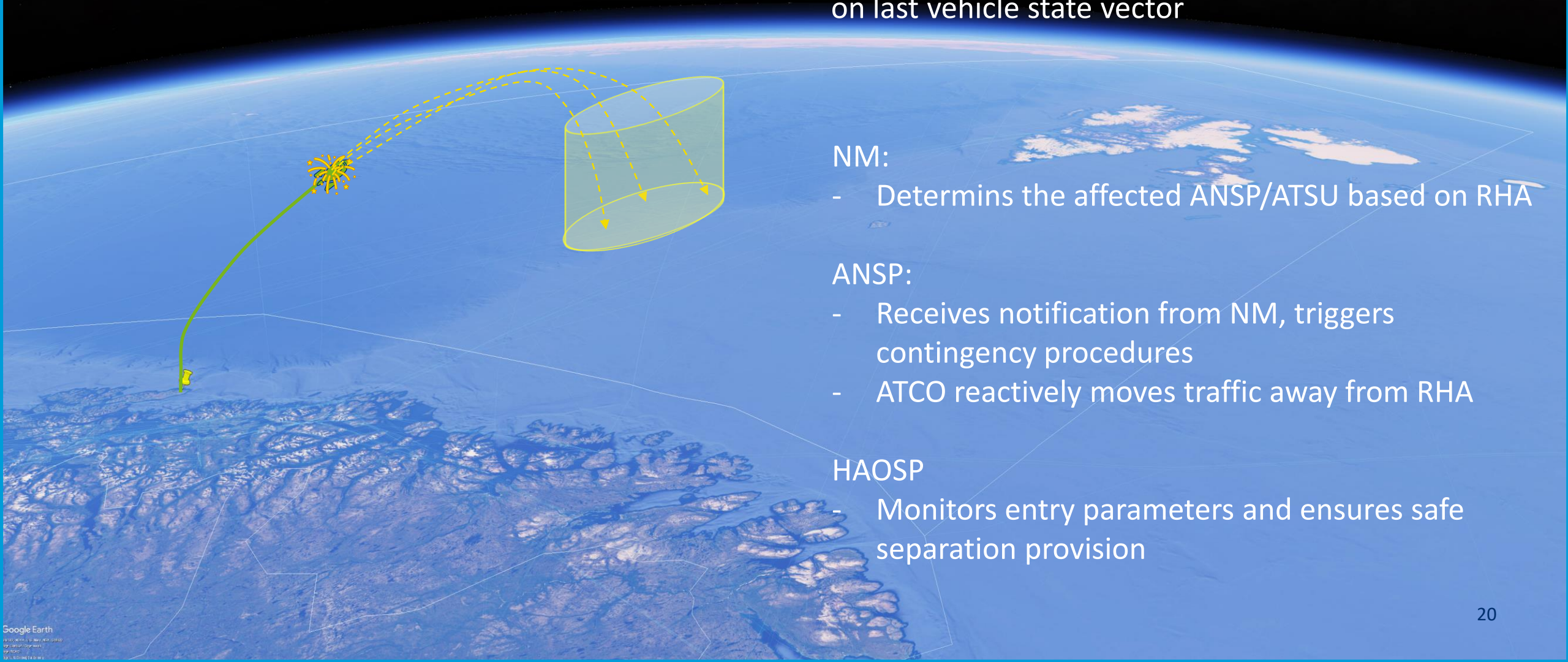
ECHO

Vertical launch to orbit

Continuation of nominal flight:

- Initial stage burned out, stage separation occurs

ECHO

Google Earth

Vertical launch to orbit

Continuation of nominal flight:

- Initial stage (+ fairing) falls back into predetermined area, protected by airspace restitions
- Upper stage continues towards space

STM

- Monitors trajectory information and predicts orbit of resulting space objects (payload, etc.)

LRO

- Confirms operation ended, initiates release of airspace restriction for the drop zone

Google Earth

Launchers
Air Launch - Expendable Rocket

Flight Freq. Europe (all launchers)
- < 2025   : 5-10 / y
- 2025-2030   : 10-20 / y
- > 2030+   : 20-40 / y

Potential airports in Europe: 5-10

Items : 5+*
- IT1   : Airplane
- IT2x : Lower stage (booster)
- IT3y : Intermediate stage
- IT4z : Upper stage
- IT5   : Payloads

// Phases in parallel —— Propelled ---- Not propelled

Altitude

~ 100 km

~ 20 km

Lower stage Separation

Fairing Separation

Mach 5-10 → Orbital velocity

IT4 – upper stage

P/L separation

IT5 - P/L

S

HA

A

Up to Mach 5-10

IT2 - lower stage

Mach 5-10 → 0

IT3 –fairing

Subsonic

Hundreds of km   Hundreds of km   Hundreds of km   hundreds of km   Thousands of km   Thousands of km   Range

< 2025

Time and airspace segregation

Trajectories monitoring

Google Earth

Air-launch to orbit

Google Earth

Air-launch to orbit

Google Earth
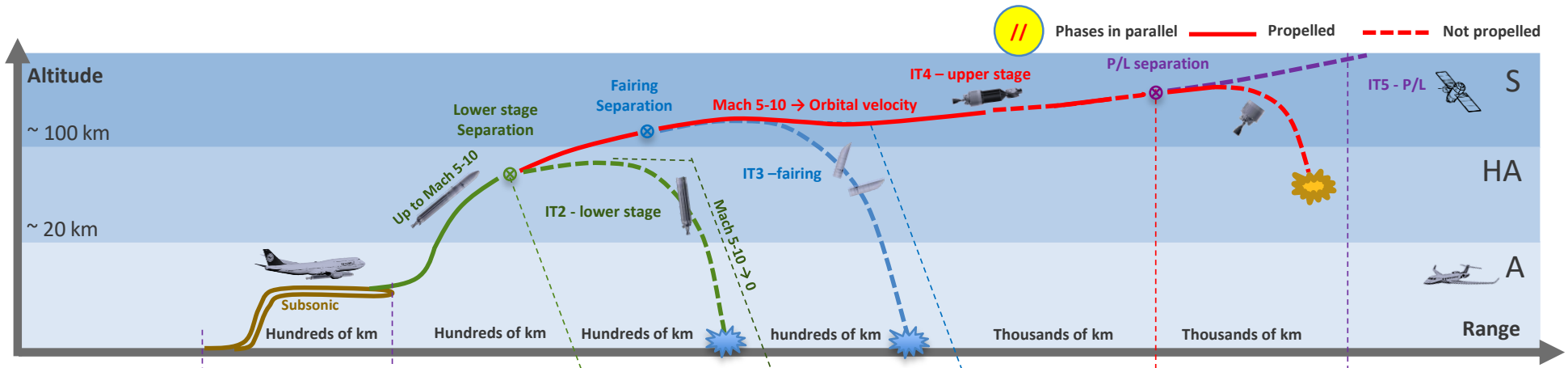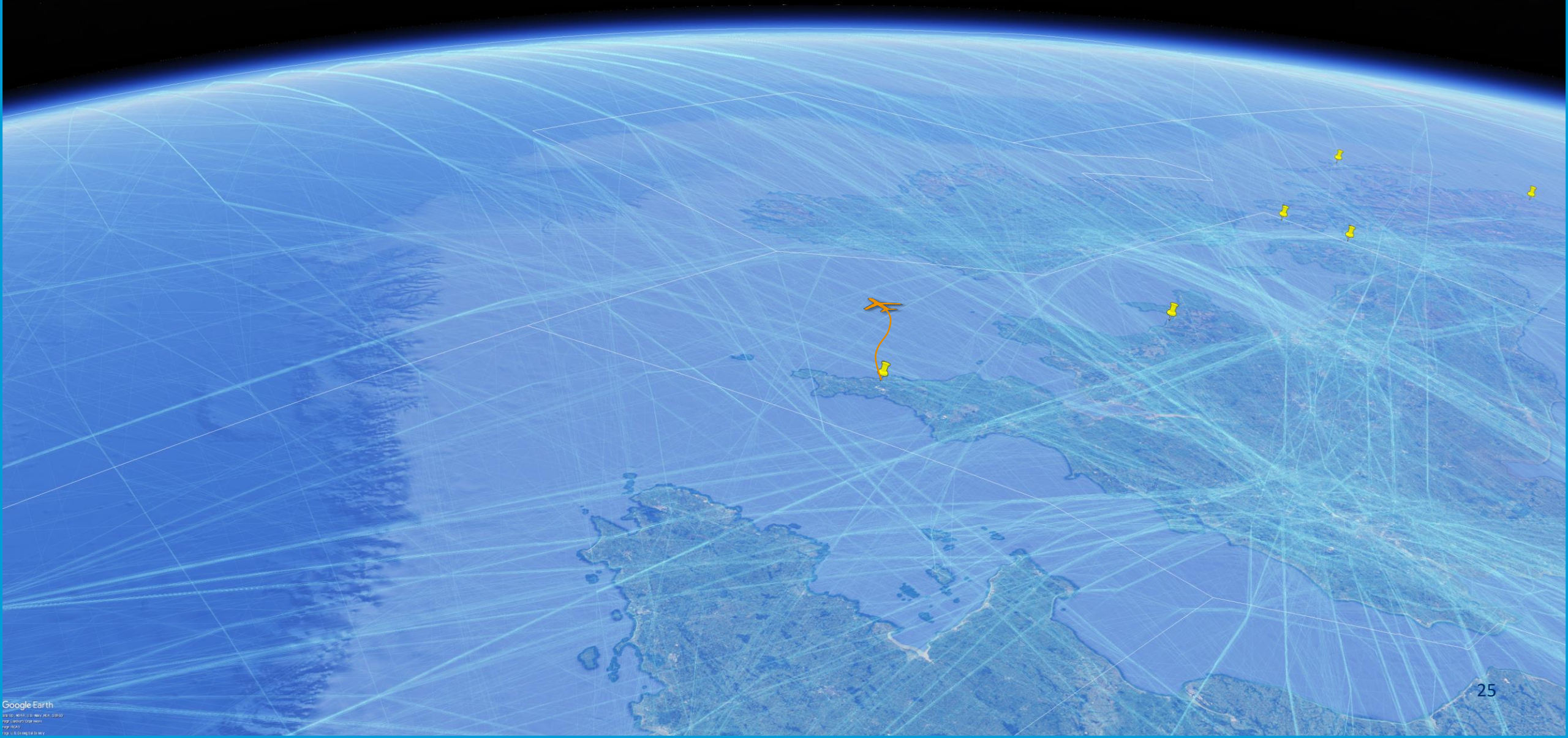
Air-launch to orbit

Air-launch to orbit

ECHO

ESA WaveRider

Capsule re-entry (SpaceX Dragon)

Spaceplane / Orbiter re-entry (Dream Chaser)

- Vertical Rocket

Launche

able Rocket
able Rocket
eusable Rocket
le Rocket
e Rocket

- RocketPlane

From Orbit ➔
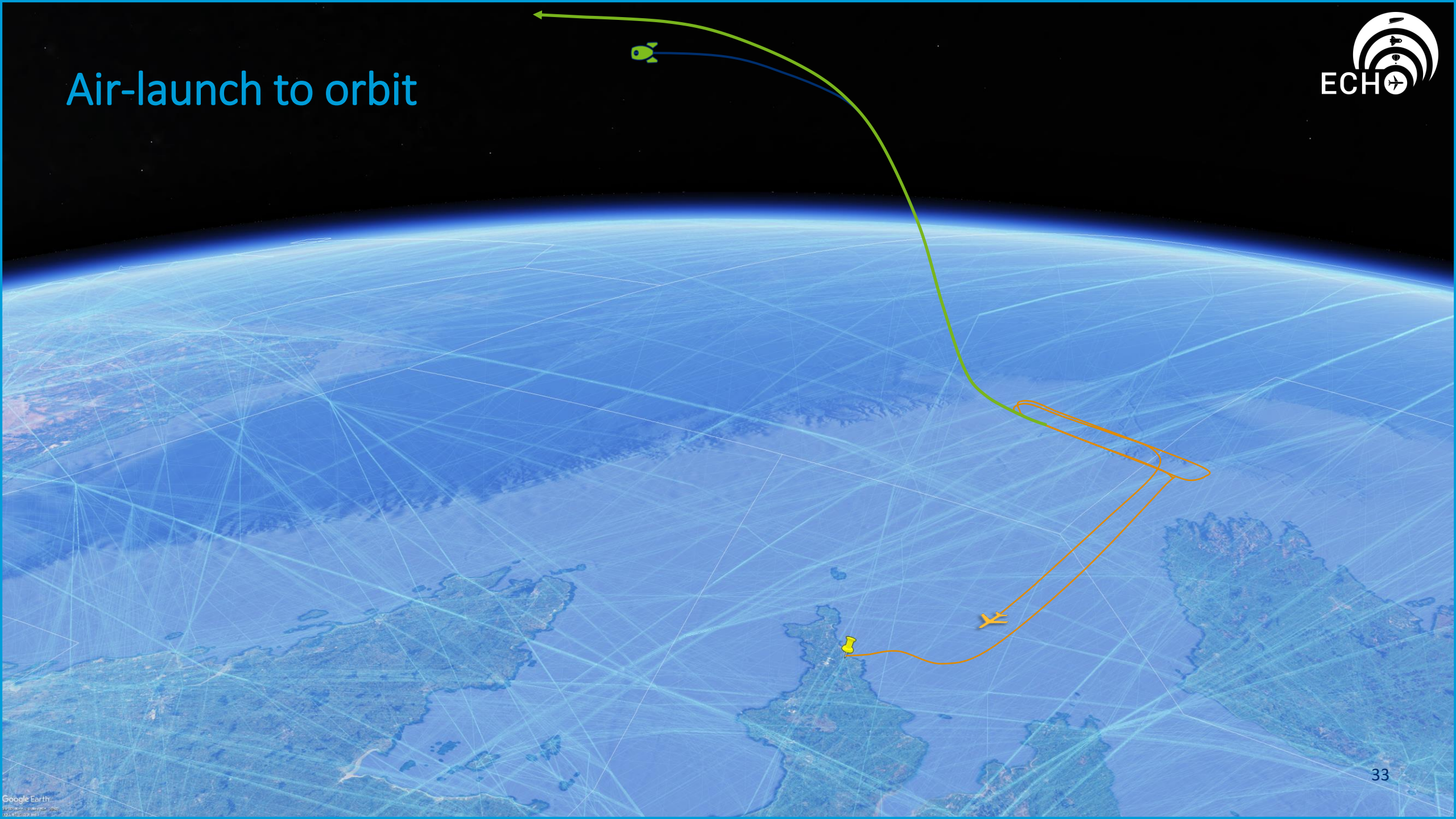
- **Re-entry vehicle**
- **Satellite de-orbit**
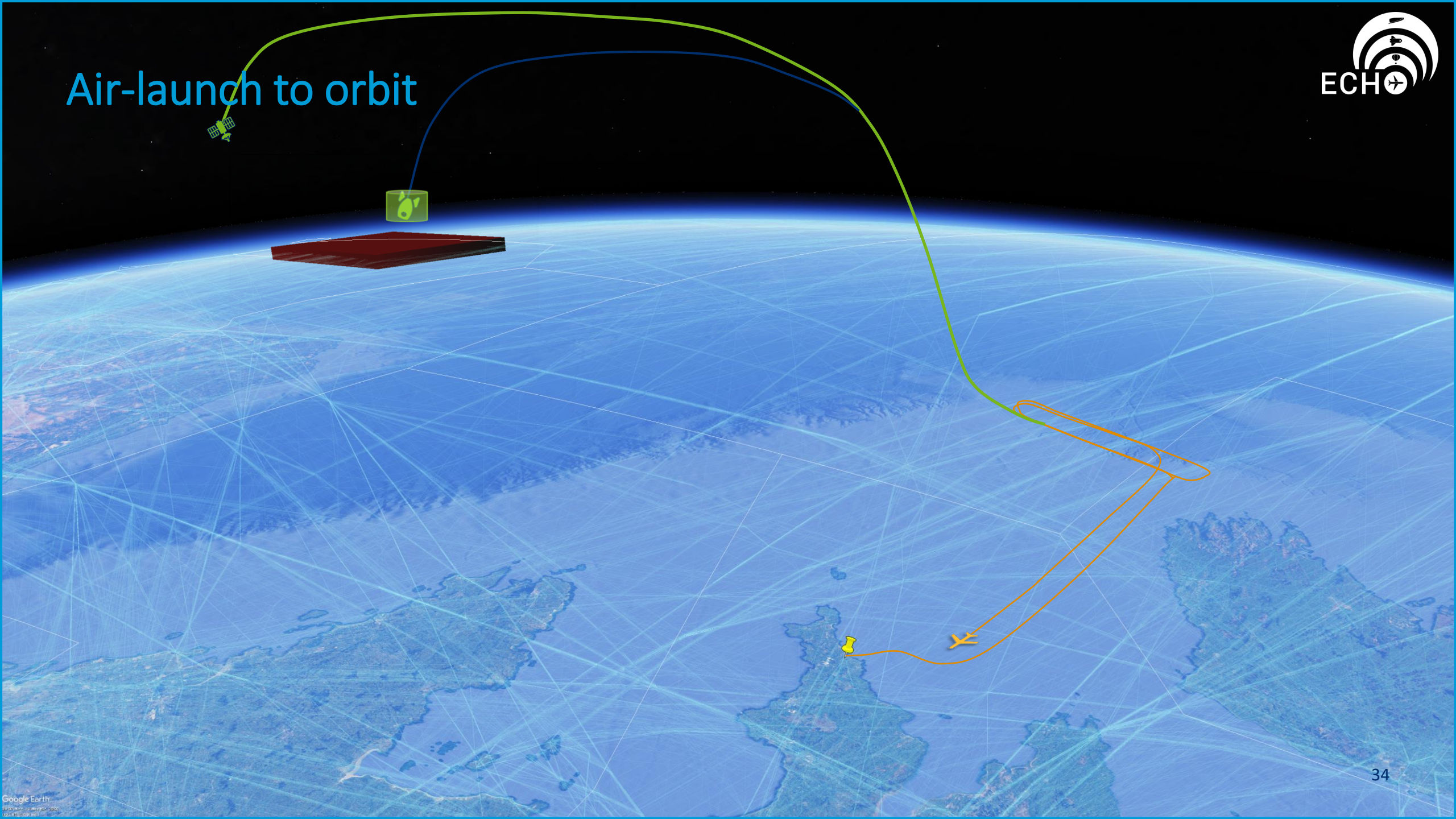
From Orbit Reentry Vehicle

Reentry Freq. Europe (all reentry vehicles)
- < 2025   : 1-2 / y
- 2025-2030   : 2-5 / y
- > 2030+   : 5-10 / y

Spaceports in Europe: 1-5

Items : 1
- IT1   : Reentry Module (RM)
- IT2   : Service Module (SM)

// Phases in parallel   ——— Propelled   - - - Not propelled

Altitude

Orbital velocity

IT1 – Reentry Module

~ 100 km

IT2 – Service Module

Mach 25+ → 2

~ 20 km

Mach 2 → 0

S

HA

A

Thousands of km   Thousands of km   Thousands of km   Tens of km   Range
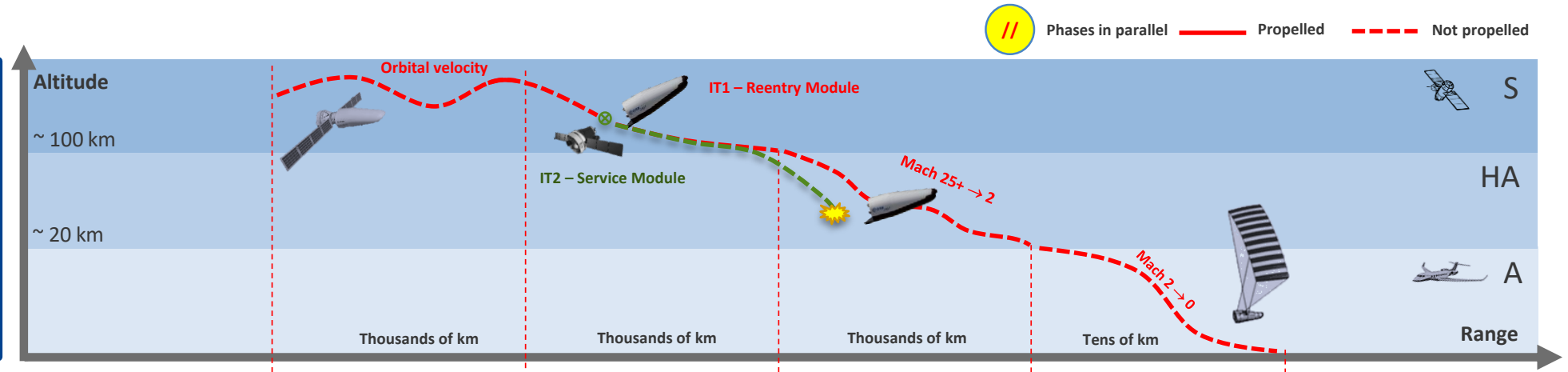
today

Time and airspace segregation

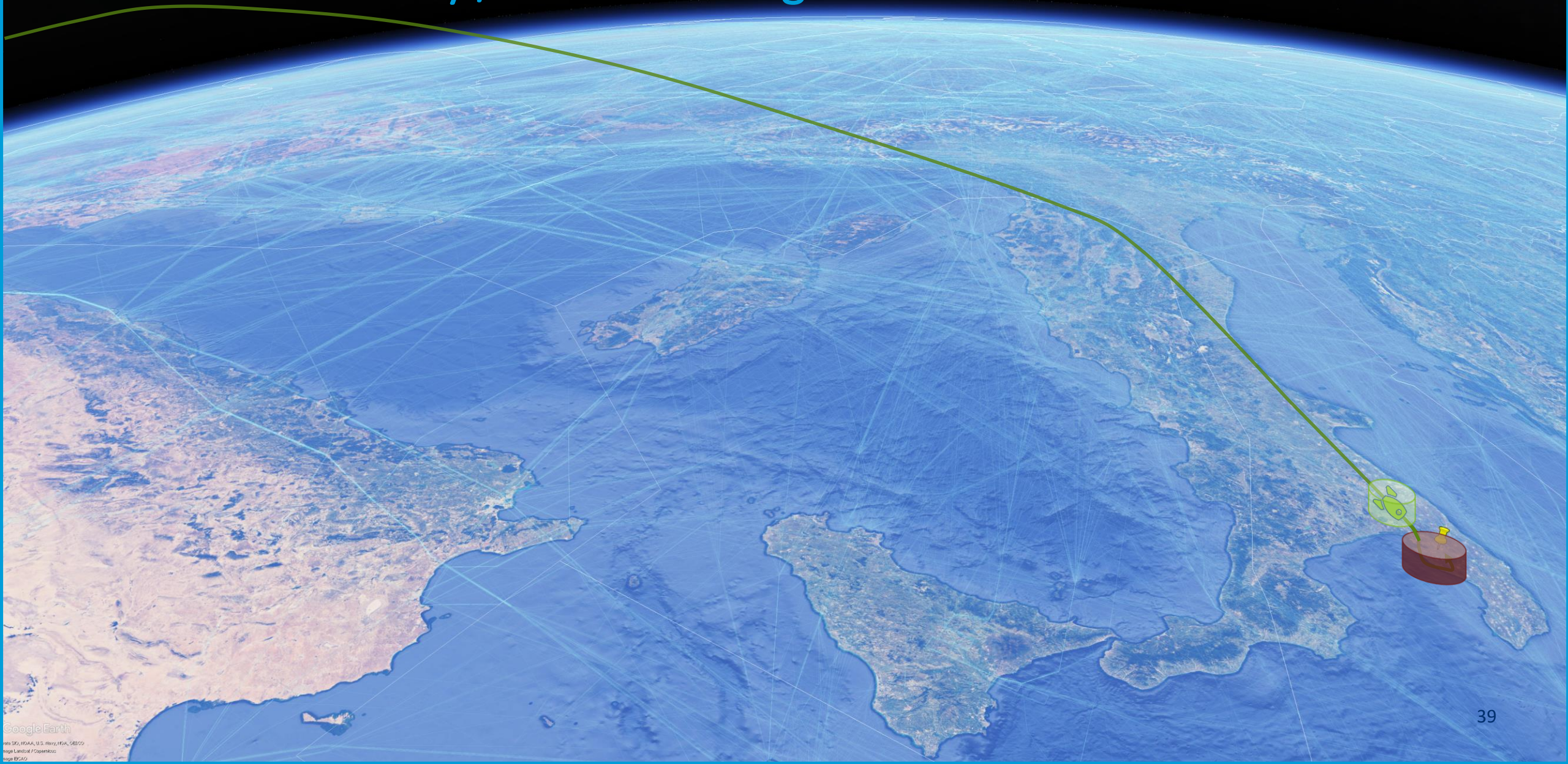Trajectories monitoring

Controlled re-entry / From-orbit flight
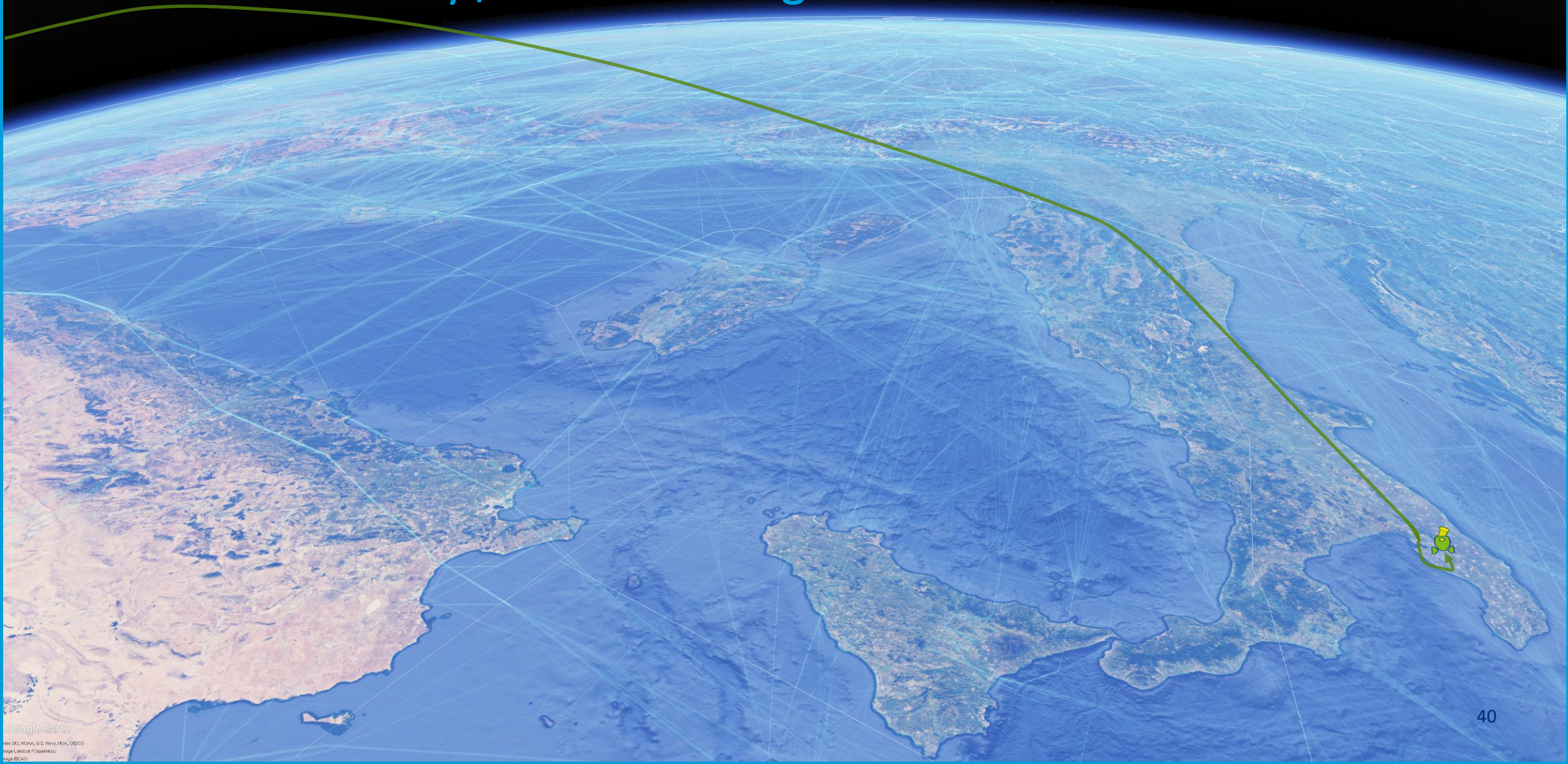
Controlled re-entry / From-orbit flight

A to A

- **Vertical Rocket**
- **Air Launch Rocket**
- **RocketPlane**

New Shepard (Blue Origin)

WhiteKnight2 / SpaceShipTwo (Virgin Galactic)

EADS rocketplane

Launcher

- Direct Launch Semi Reusable Rocket
- Direct Launch Reusable Rocket
- Air Launch Expendable Rocket
- RocketPlane

From Orbit

- Re-entry vehicle
- Satellite de-orbit

A to A Suborbital Air Launch
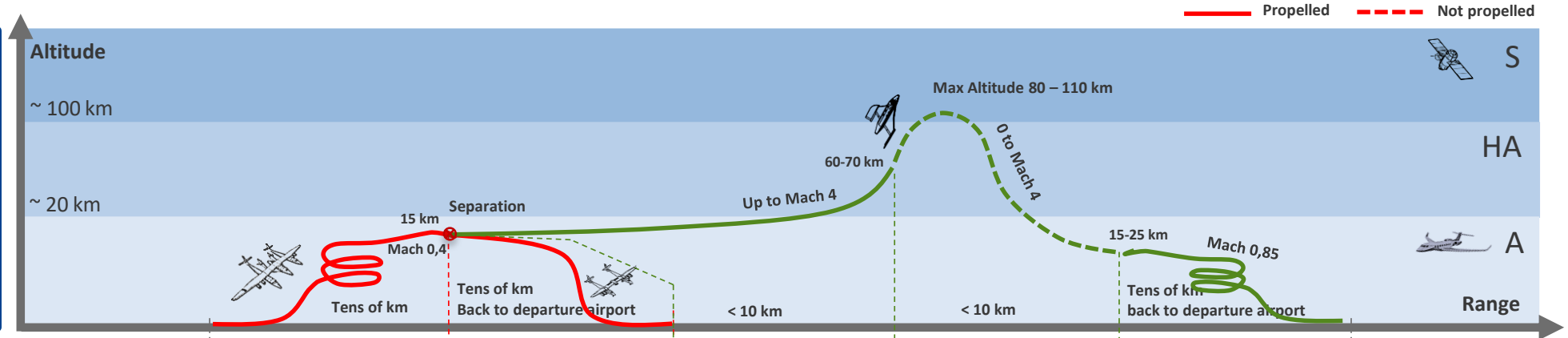

Flight Frequency in Europe
- < 2025   : 0 - 10 / y
- 2025-2030   : 0 - 50 / y
- > 2030   : 100 / y

Spaceport in Europe: 1-3

Items : 2
IT1 : Airplane (WK2)
IT2 : Spaceplane (SS2)

Propelled — — Not propelled

Altitude
~ 100 km
~ 20 km

Max Altitude 80 – 110 km
60-70 km
Up to Mach 4
0 to Mach 4
15-25 km
Mach 0,85

Separation
15 km
Mach 0,4
Tens of km
Tens of km
Back to departure airport
< 10 km
< 10 km
Tens of km
back to departure airport

S
HA
A
Range

< 2030

On demand trajectory change

Re-routing / Emergency landing

Trajectory monitoring

A to A

Google Earth

ECHO

Google Earth
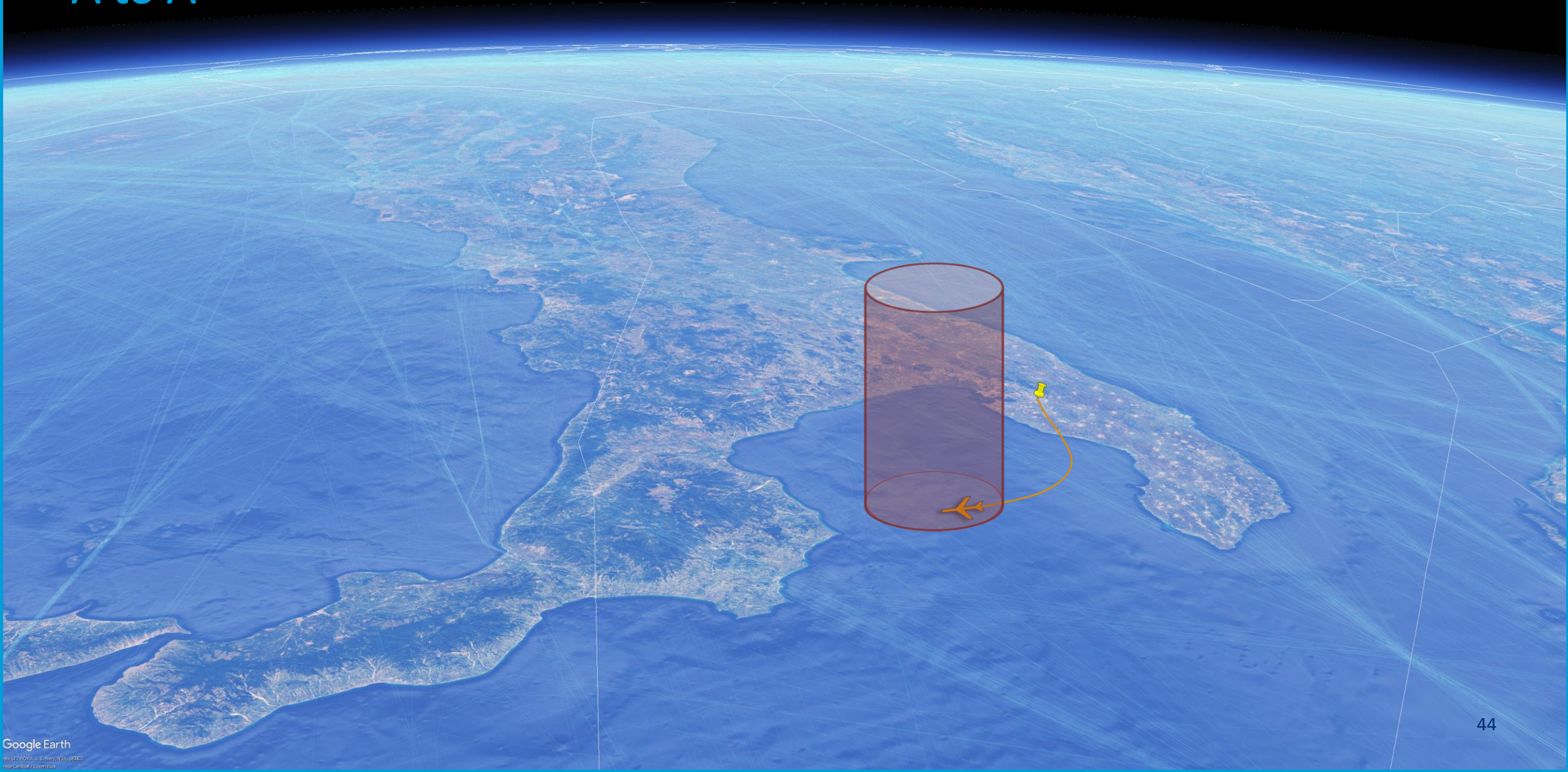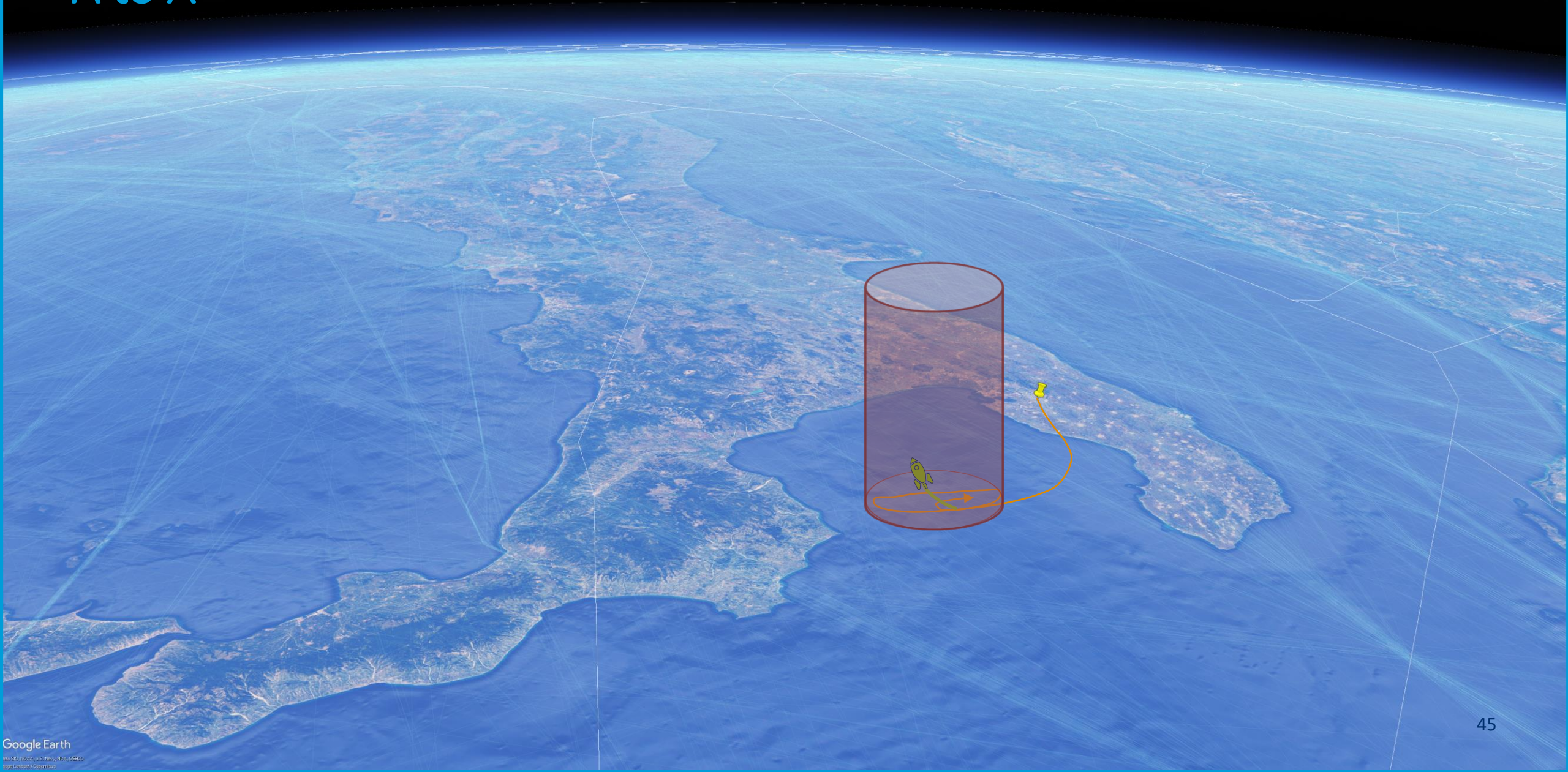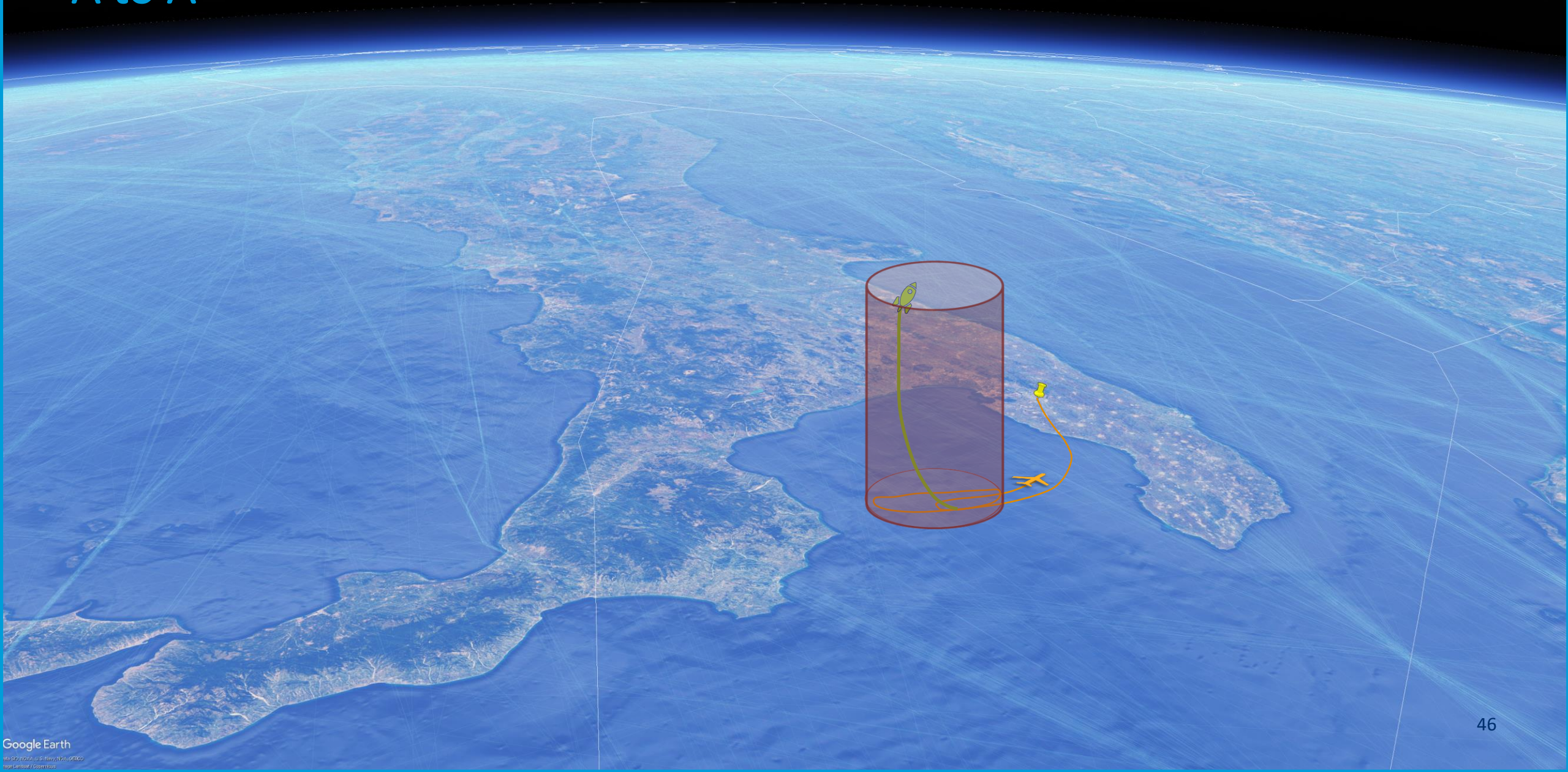
Boom Overture

Aerion AS3

Aerospatiale / BAC Concorde

A to B

→ • **Supersonic Airplane**
→ • **Hypersonic Aircraft**
→ • **Hypersonic Spacecraft (Horizontal L.)**
→ • **Hypersonic Spacecraft (Vertical L.)**

Hermeus Alcyon concept

Boeing hypersonic

Stratofly

Starship

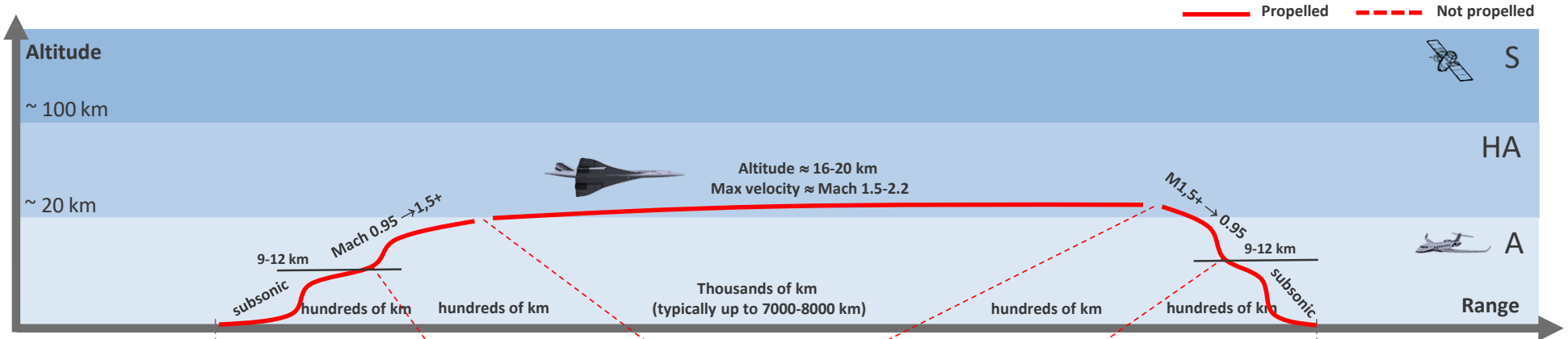Spaceliner concept

Falcon XX concept

A to B
Hypersonic Spacecraft (vertical landing)
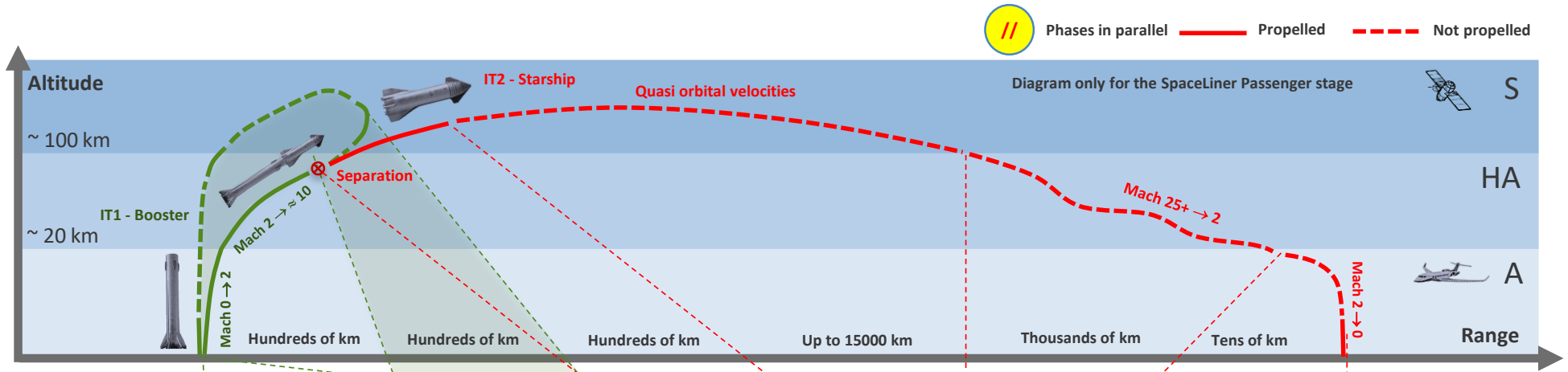

Flight Frequency in Europe
- < 2025   : 0 / y
- 2025-2030   : 0 - 1 / m
- > 2030++   : 0 - 5 / m

Spaceports in Europe: 1-5 (coastal only)

Items : 2
- IT1 : Booster
- IT2 : Starship

// Phases in parallel — **Propelled** --- **Not propelled**

Altitude

~ 100 km

~ 20 km

IT1 - Booster

IT2 - Starship

Quasi orbital velocities

Diagram only for the SpaceLiner Passenger stage

S

HA

A

Mach 2 → ≈ 10

Separation

Mach 0 → 2

Mach 25+ → 2

Mach 2 → 0

Hundreds of km   Hundreds of km   Hundreds of km   Up to 15000 km   Thousands of km   Tens of km

Range

> 2025

Time and airspace segregation

No trajectory change
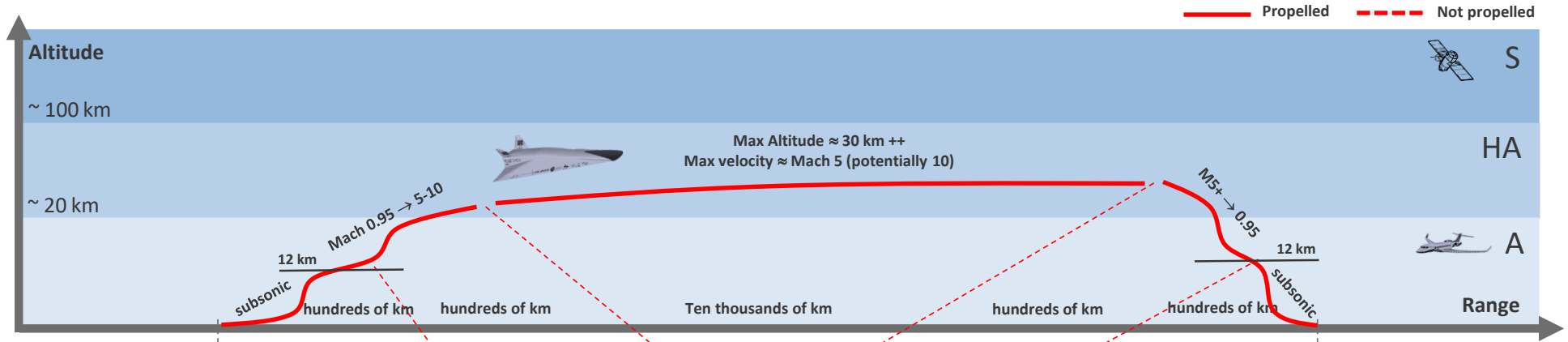
A to B
Hypersonic Aircraft

Flight Frequency in Europe
- < 2025   : 0 / y
- 2025-2030   : 0 / y
- > 2030++   : 0-20 / day

Airports in Europe: 5-10

Items : 1 airplane

Propelled — — — Not propelled

Altitude
~ 100 km
~ 20 km

S
HA
A
Range

Max Altitude ≈ 30 km ++
Max velocity ≈ Mach 5 (potentially 10)

Mach 0.95 → 5-10
M5+ → 0.95
12 km
12 km
subsonic
subsonic
hundreds of km   hundreds of km   Ten thousands of km   hundreds of km   hundreds of km
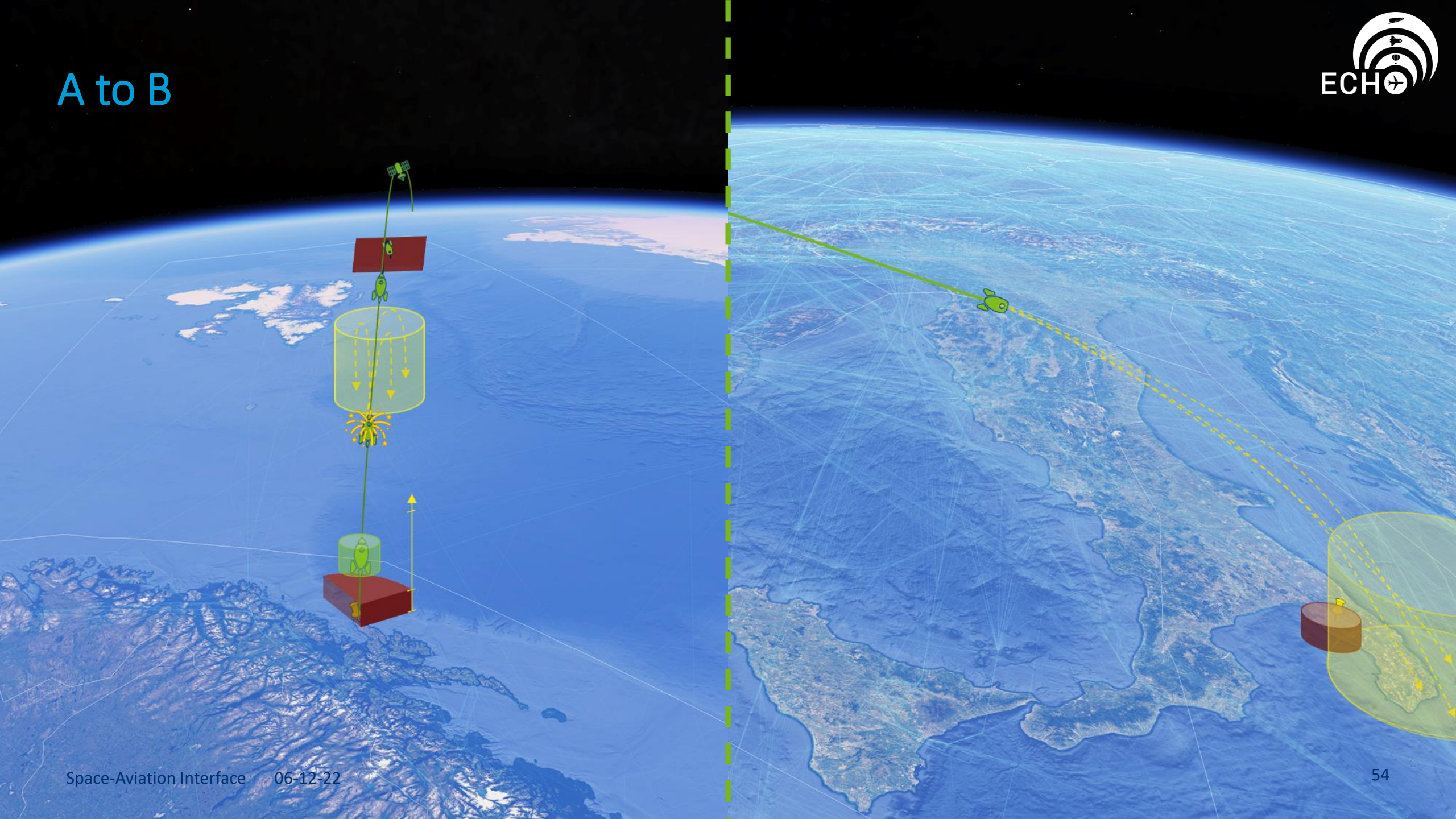
> 2030+

Time or airspace segregation

Reduced trajectory change

Trajectory monitoring

A to B

THANK YOU FOR
YOUR ATTENTION