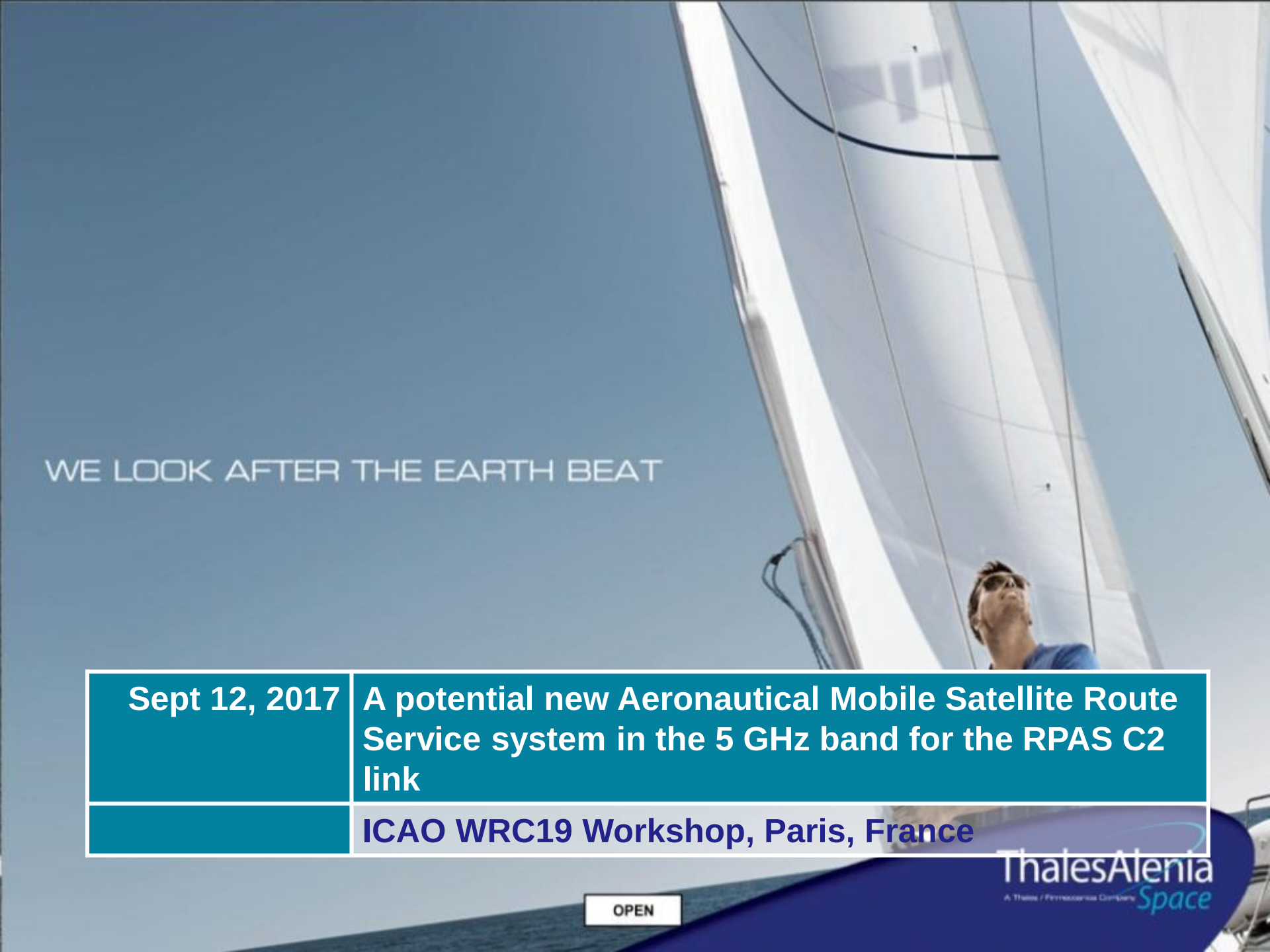


| | |
|---|---|
| **Sept 12, 2017** | **A potential new Aeronautical Mobile Satellite Route Service system in the 5 GHz band for the RPAS C2 link** |
| | **ICAO WRC19 Workshop, Paris, France** |

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# Command and Control (C2) link



RPA

## Command and Control (C2) link

- Telecontrol & Telemetry, i.e. Command & Control data
- Air Traffic Control (ATC) voice & data
- Situational awareness data, including optional Video

Remote Pilot Station

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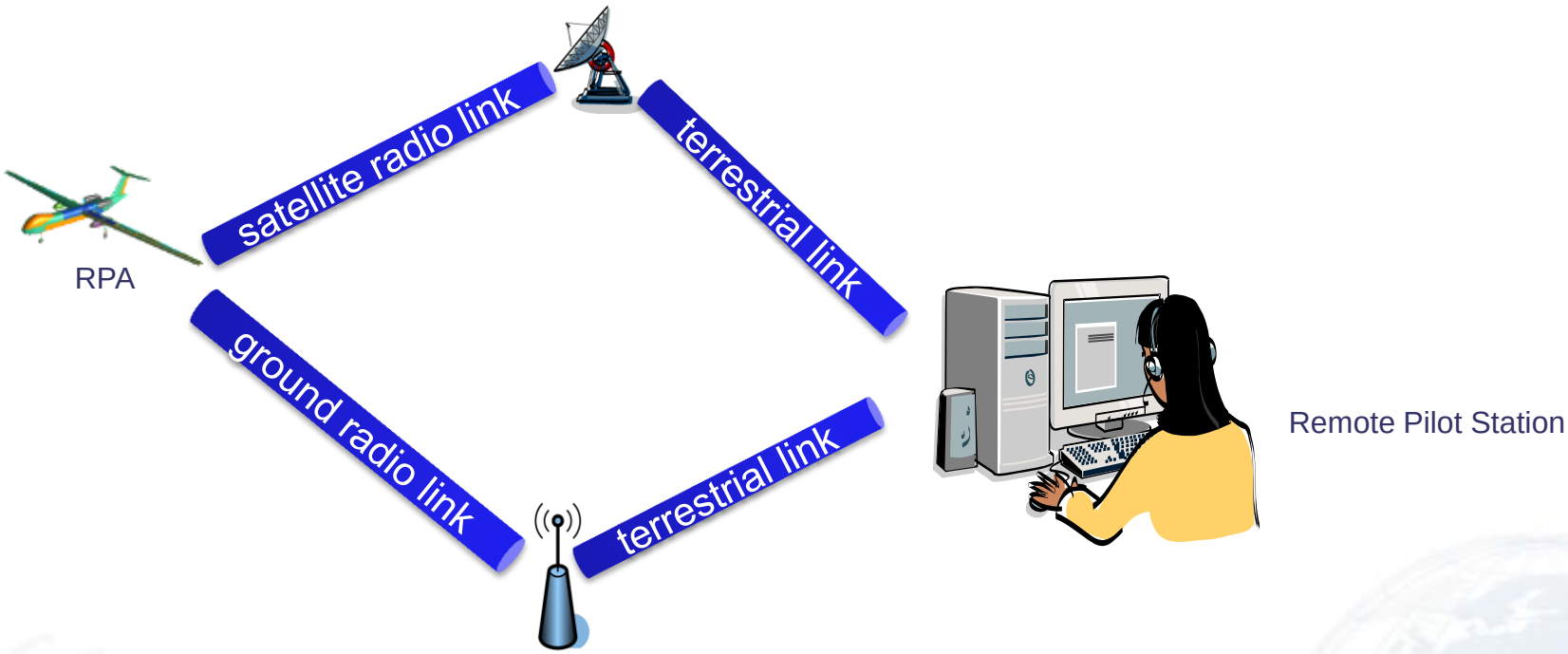
# Command and Control (C2) link – Hybrid System view



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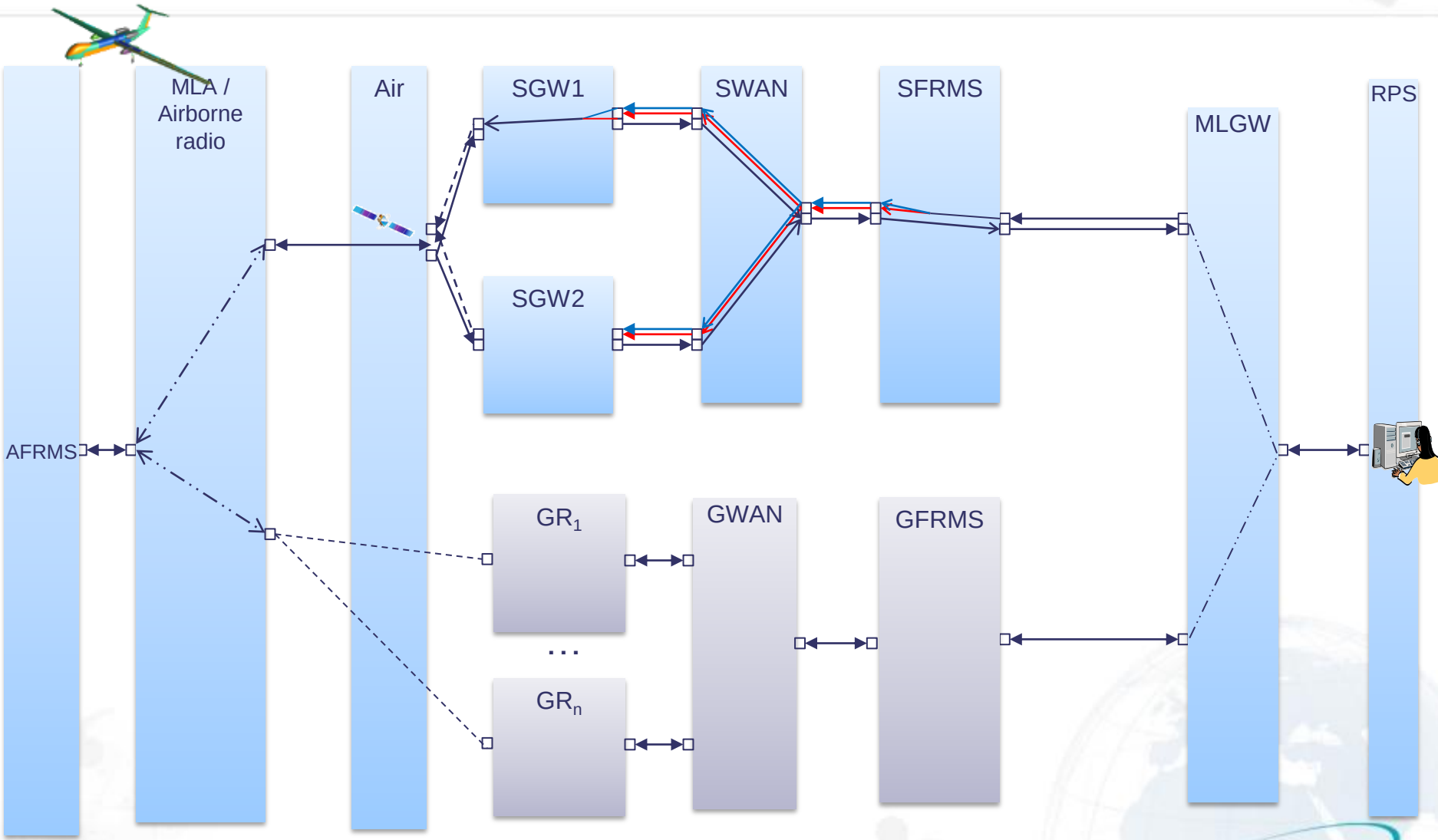
# Communication chain (user traffic)






AFRMS Aircraft Flight & Radio Management system
GFRMS Ground Flight & Radio Management system
SFRMS Satellite Flight & Radio Management system
MLA Multi-Link Adaptor
SGW Satellite GateWay

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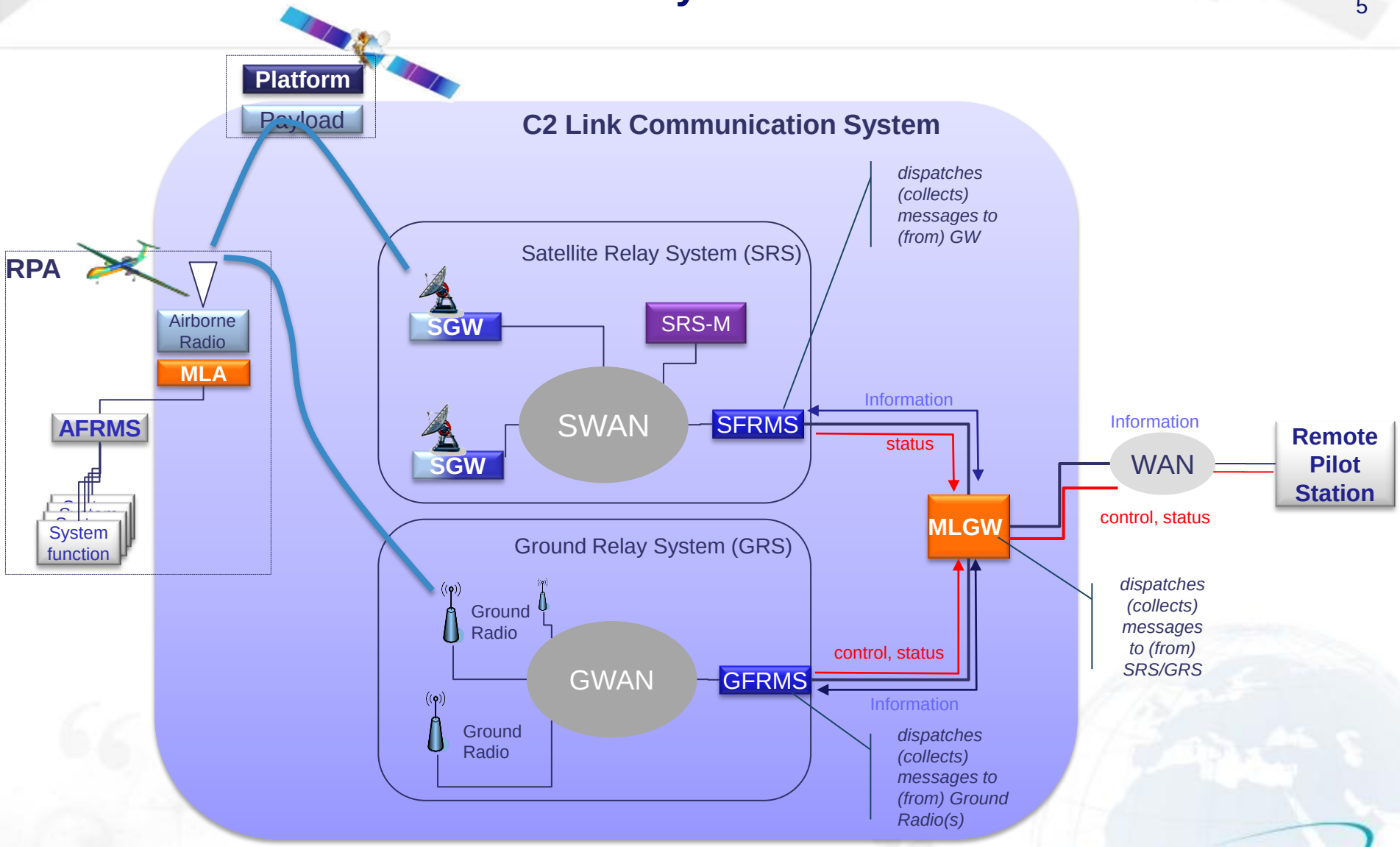
# The 5GHz Solution – Detailed System View






AFRMS Aircraft Flight & Radio Management system
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MLA Multi-Link Adaptor
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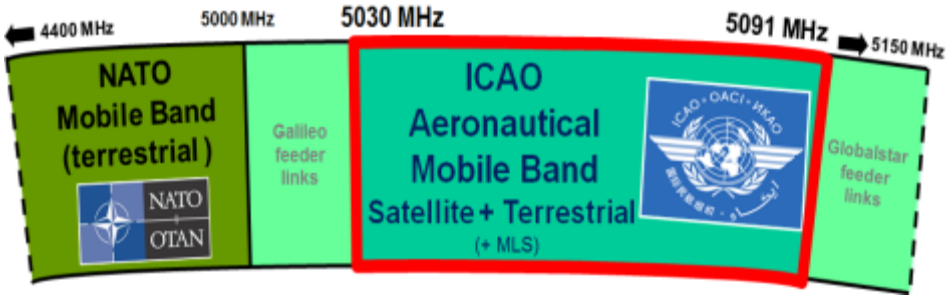
# The 5GHz Solution – Spectrum: 5030-5091 MHz






- **61 MHz exclusively allocated worldwide to civil aviation services**
  - **Terrestrial & Satellite** Communication
  - Compatibility with existing system is ensured (see FSMP WG/3 WP10)
- Low rain attenuation ➔ all-weather operation with low cost and low SWaP (Size Weight and Power) airborne terminal
- **Terrestrial C2 link systems are likely to use this allocation** (where the 960-1164 MHz spectrum is already congested, e.g. in Europe) – MOPS exists (DO-362)
- **C-Band SATCOM MOPS** being prepared at EUROCAE WG-105

**A global and unified C2 link capability offering through a single equipment an universal access to all civil airspace classes worldwide**

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# The 5GHz Solution – 5030-5091 MHz frequency band sharing



## See FSMP-WG03-WP10

"Spectrum Sharing in C band for terrestrial and satcom C2 link for RPAS"

**CONCLUSION**

Sharing of the band can be achieved with limited operational impact

## See FSMP-WG04-WP09

"Considerations for establishment of channel plans for the AMS(R)S and AM(R)S allocations in the 5030-5091 MHz frequency band for use by satellite and terrestrial systems supporting UAS C2 Links"

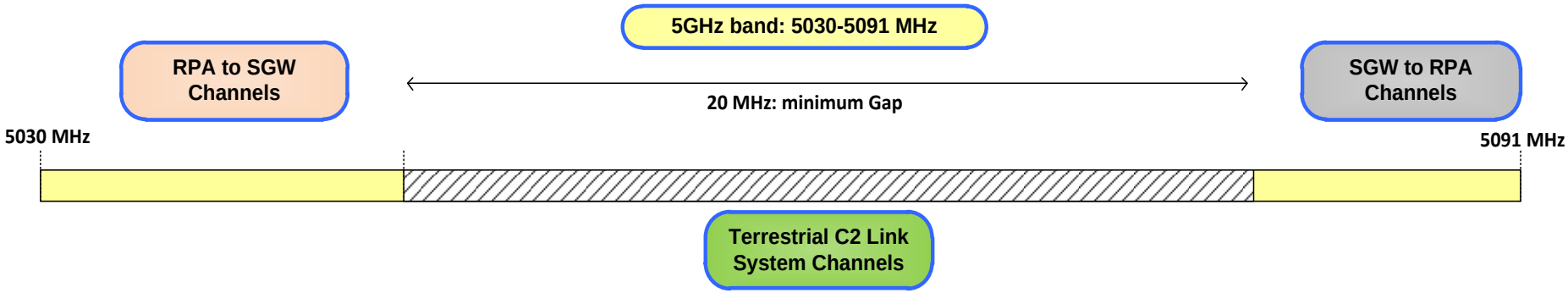
**CONCLUSION**

It is possible to define a carrier assignment strategy in the band that will limit coordination requirements to a minimum

# The 5GHz Solution – 5030-5091 MHz frequency band sharing



- **Satellite System Channels**
  - 300 kHz to 1 MHz channels with flexibility between SGW and RPA
  - 40 kHz to 100 kHz channels with flexibility between RPA and SGW




- A sharing that **can be flexible** depending on the geographical region

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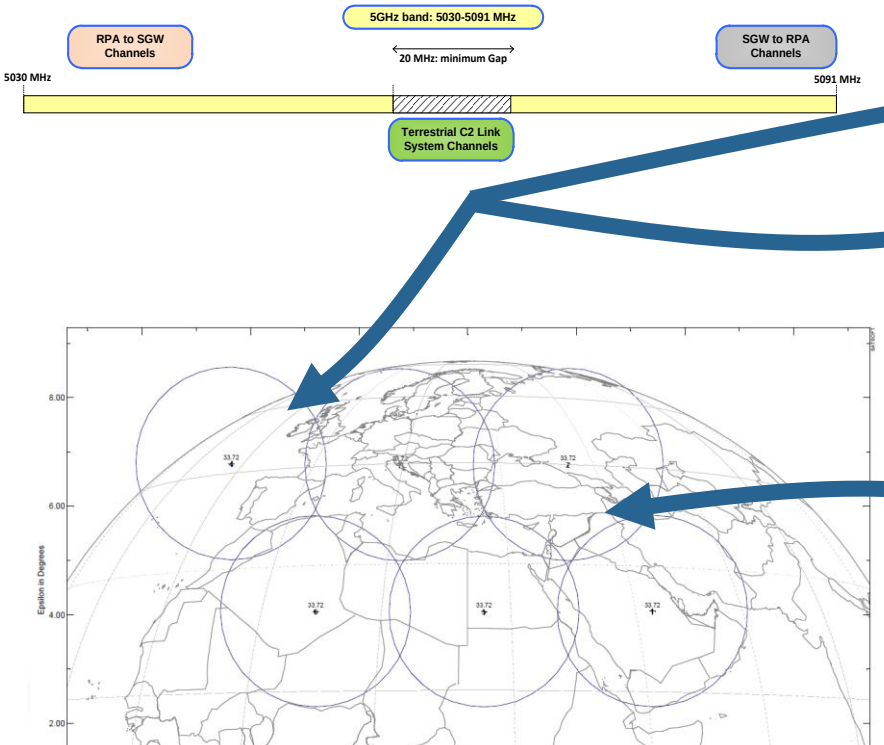
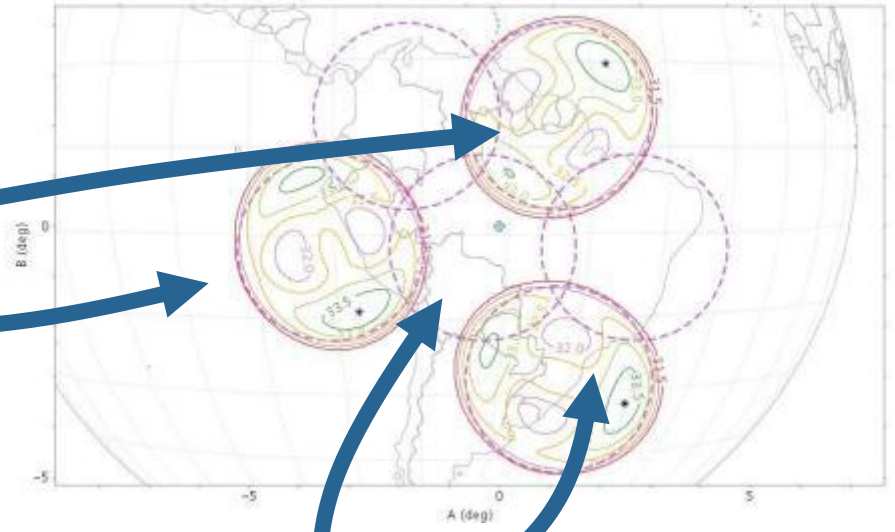
# The 5GHz Solution – 5030-5091 MHz frequency band sharing



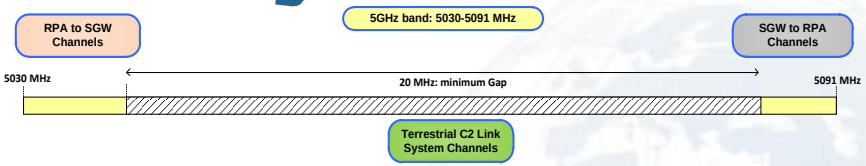
## A sharing that can be flexible depending on the geographical region







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# The 5GHz Solution – Ongoing activities



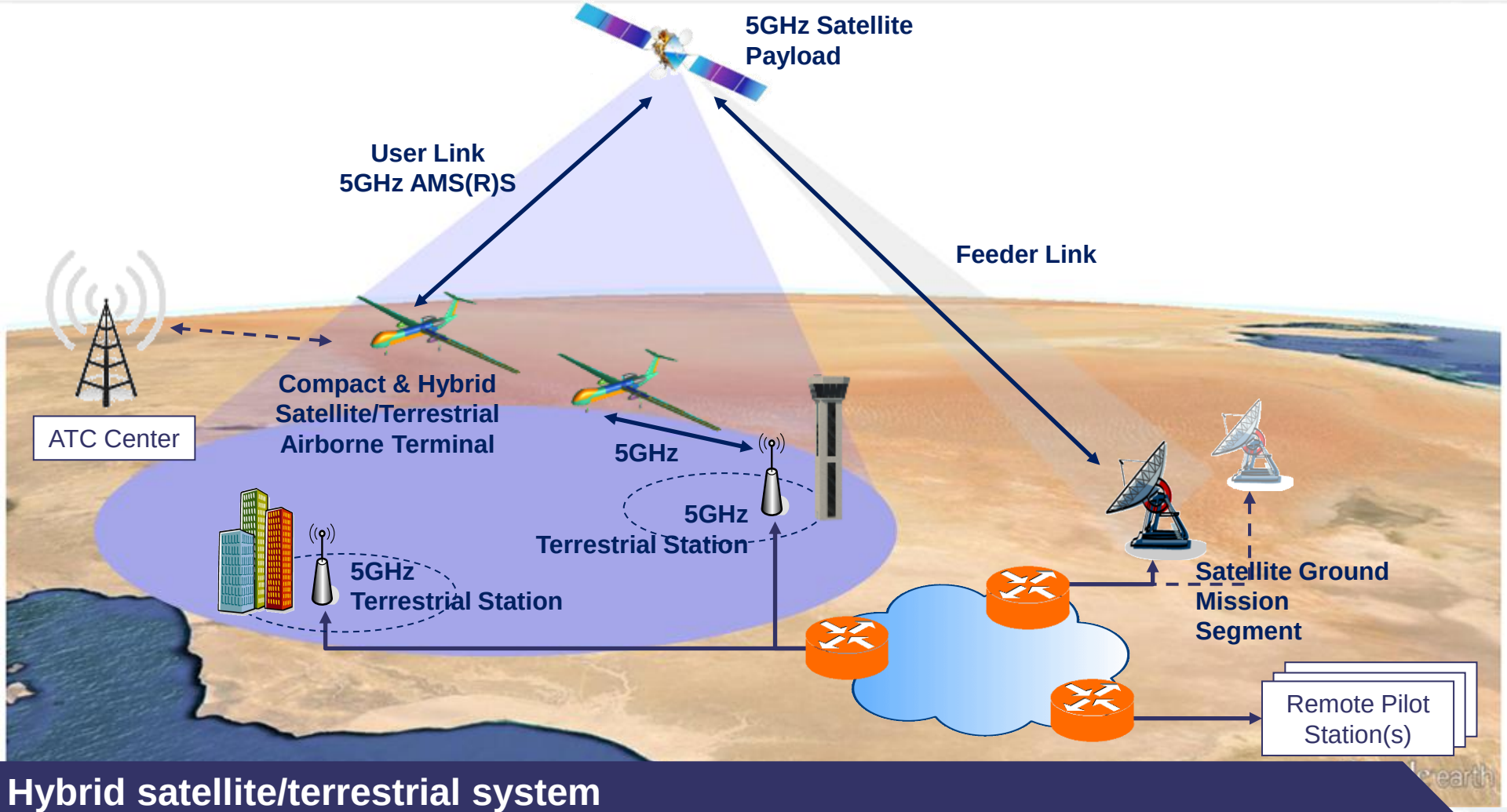
- **EUROCAE WG-105 (ex WG-73) will continue work on C2 in Control Command, Communications & Security (C3S) Focus Team**
  - **Spectrum management**
    - MASPS on spectrum management under elaboration
  - **SATCOM data-link**
    - MOPS expected in 2018
- 5GHz Band is also considered by **RTCA** SC-228 but focusing mainly on terrestrial activities (DO-362 update)

MASPS: Minimal Aeroautical Service Performance Specifications

MOPS: Minimal Operational Service Performance Specifications

# The 5GHz Solution – Overall Architecture






**Hybrid satellite/terrestrial system**
**Large coverage area ensuring very high safety performance where needed**

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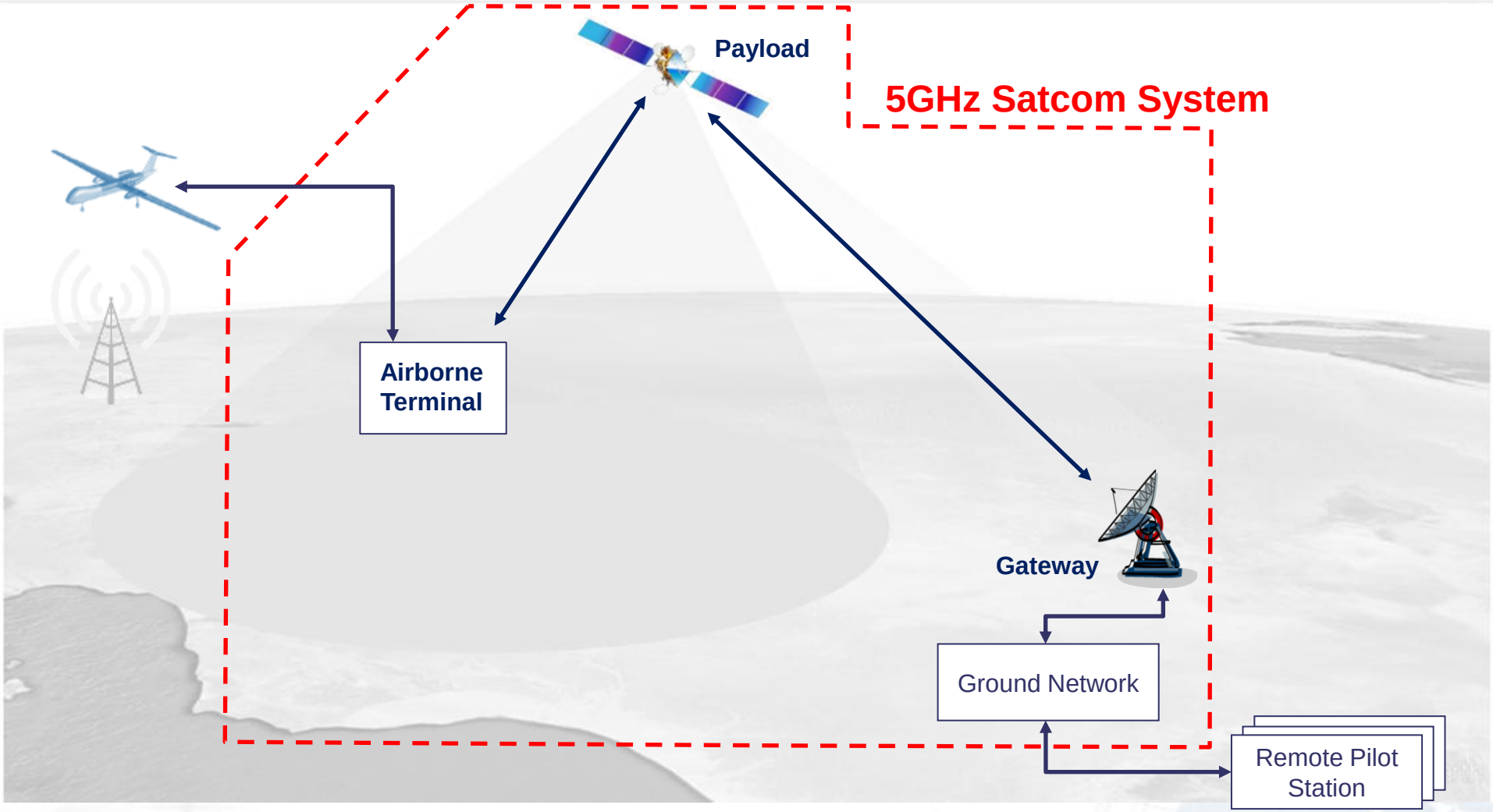
# The 5GHz Solution – Perimeter



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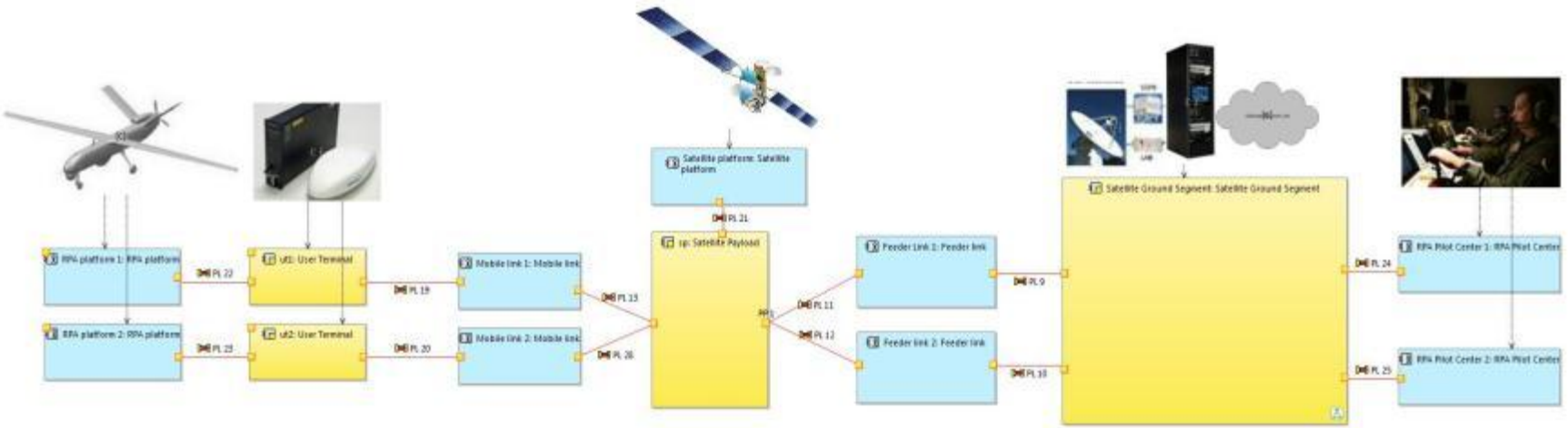
# The 5GHz Solution – System Physical Architecture






- **C2 Link Ground Segment**:
  - provides connectivity to the RPA (Remote Piloted Aircraft) pilot centers
- **C2 Link Satellite Payload**:
  - hosted payload onboard a satellite platform
- **C2 Link User Terminal**:
  - onboard the RPA, provides C2 link Connectivity to the RPA Platform

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# The 5GHz Solution – C2 Link Ground Segment



- **Communication protocol tailored to the need**
  - **Forward Link – from SGW to RPA:**
    - TDMA, i.e. several RPA are multiplexed over a single carrier
    - Continuous Transmissions using CPM Modulation
    - High efficiency waveform delivering 10^-3 PER
  - **Return Link – from RPA to SGW:**
    - FDMA, i.e. each RPA uses its own carrier
    - Burst Transmissions using CPM Modulation
    - High efficiency waveform delivering 10^-3 PER
- **Redundancy mechanisms between multiple sites – Availability > 99.99%**

**A simple and robust ground segment**

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# The 5GHz Solution – C2 Link Airborne User Terminal



- **Simple:** no diplexer, no antenna pointing mechanism
- **Low Size, Weight and Power** compatible with light drones
- **Small antenna footprint,** limited accommodation constraint
- **Hybrid Satellite/Terrestrial terminal**
- **Dual use :** Civil (5030-5091MHz) & Military (4.4-4.9GHz)

**Example of existing** aero C-band antenna (ANTCOM)
5cm (W) x 13cm (L) x 8cm (H)
150g

**Hybrid terrestrial/satellite airborne terminal + dual use opportunity**
**➔ Satellite connectivity without any additional hardware**

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# The 5GHz Solution – System Specifications – Overview (1/2)



| Category | Specifications |
|---|---|
| **Interfaces** | IP with Remote Pilot Centers<br>IP with Communication Management Unit onboard RPA |
| **Functional** | Transmit IP datagrams<br>Indicate the quality of the link<br>Support Remote Pilot Center handovers<br>Implement QoS differentiation |
| **Security** | Strong Authentication during logon phase<br>Source Authentication & Non-Repudiation of control plane exchanges |
| **Performances** | **Coverage:** regional, extensible to global coverage<br>**Capacity:** from ~ 100 RPAs simultaneously, to up to 10 000<br>**Latency** (99.9% over 1 month): C2: 0.5s, ATC voice: 0.4s, ATC data: 3s, SA: 0.7s<br>**Availability:** >99.99% |

# The 5GHz Solution – System Specifications – Overview (2/2)



| Parameter | FWD | RTN |
|---|---|---|
| **Duplexing** | Frequency Division Duplex | |
| **Physical Layer** | | |
| **Channel Bandwidth** | 300kHz to 1MHz | 40kHz to 100 kHz |
| **Modulation** | Continuous Phase Modulation (CPM) | Continuous Phase Modulation (CPM) |
| **Offered bitrate** | From 150 to 500 Kbps | Up to 35 Kbps |
| **Link Layer** | | |
| **Access Mechanism** | TDMA–terminal listens to 1 shared carrier (Dynamic Timeslot Allocation) | FDMA–1 dedicated RTN carrier per user |
| **Network Layer** | | |
| **Protocol** | IP | IP |
| **Control plane** | | |
| **Authentication** | Strong Authentication during logon phase<br>Source Authentication & Non-Repudiation of control plane exchanges | |
| **Handover** | Carrier & Beam handover | |

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# The 5GHz Solution – Typical Session



**Prior Knowledge:**
- Security Credentials
- Initial RX frequency

- **RPAS logs on to the system (establishes communication)**
  - Listens to SGW transmissions on initial frequency
  - Discovers the “logon” transmit frequency to use
  - Initiates the logon process on this frequency (random access is used here)
  - Receives a dedicated carrier frequency allocation for TX, optionally, is also given a different frequency for RX

**Roles for logon:**
- Broadcasts SysInfo
- Assigns channels to RPA
- Authenticates Users

## Security Considerations

- UT authenticates the SGW as legit (strong auth)
- SGW authenticates the UT as legit (strong auth)
- All subsequent exchanges are signed:
  - Ensuring source authentication
  - Allowing for non-repudiation

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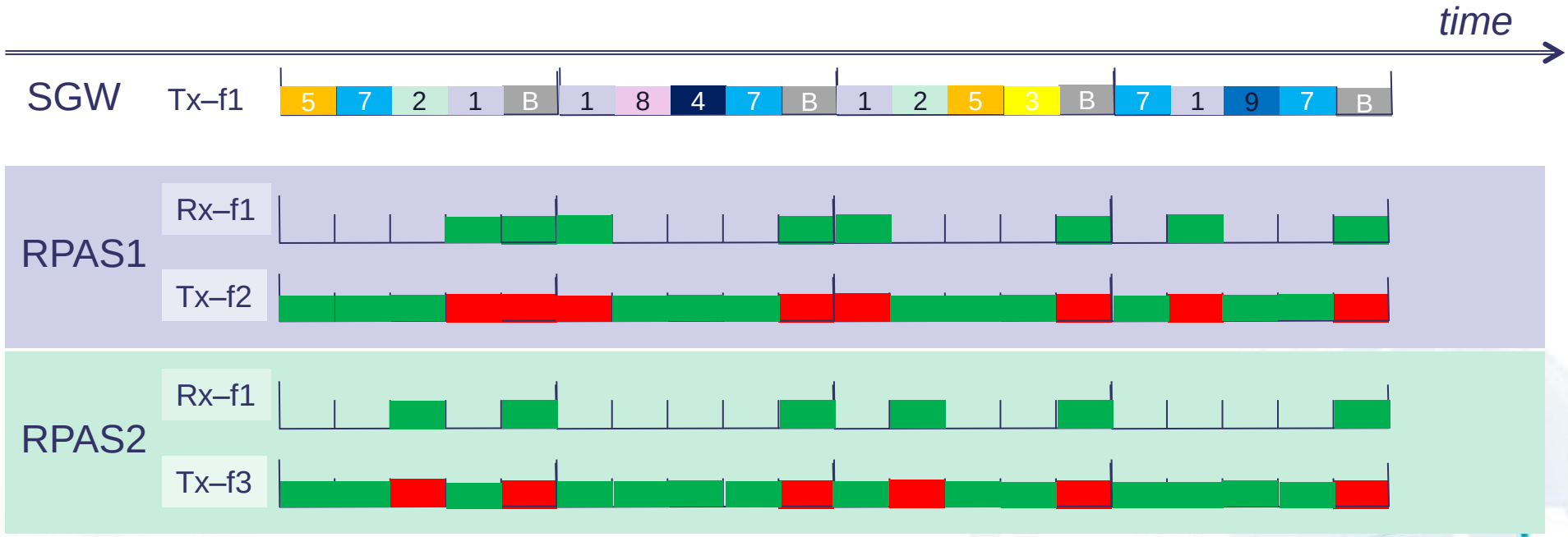
# The 5GHz Solution – Multiplexing & Access Scheme



- **Multiplexing & Access Scheme**
  - **Airborne Terminal:** half duplex mode (no diplexer), i.e. sequential Tx/Rx, with a RF filter over the complete band
  - **Satellite payload:** full duplex mode
  - **Satellite Gateway:** full duplex

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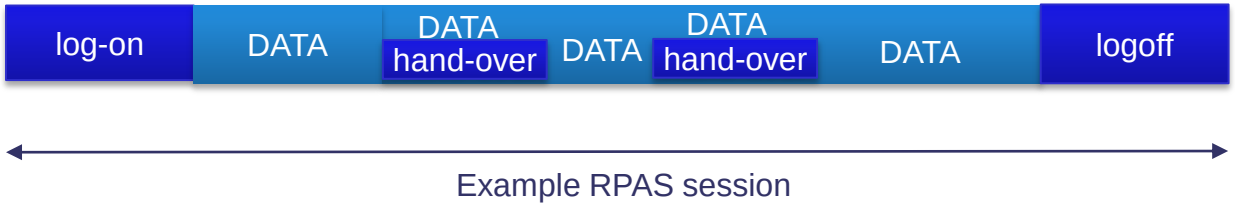
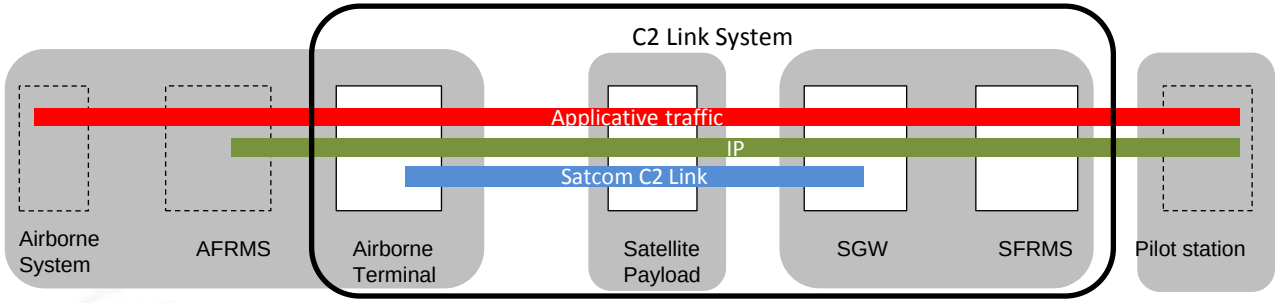
# The 5GHz Solution – Typical Session

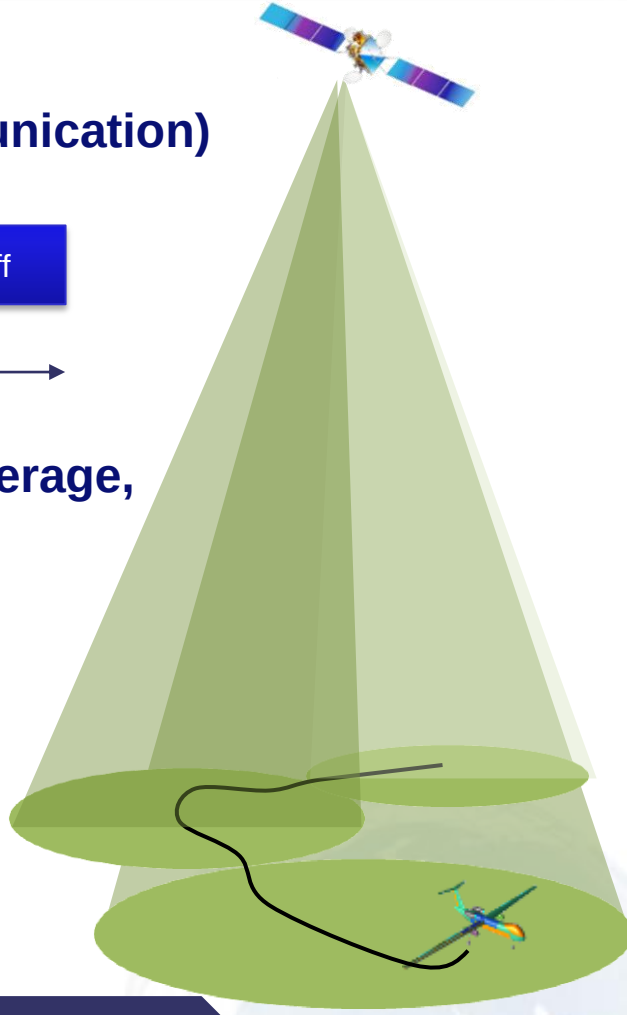


- **RPAS logs on to the system (establishes communication)**




- **Seamlessly, as the RPAS progresses on the coverage, handover(s) take place to ensure continuity**



**Always available end-to-end connection between RPA and RPS**

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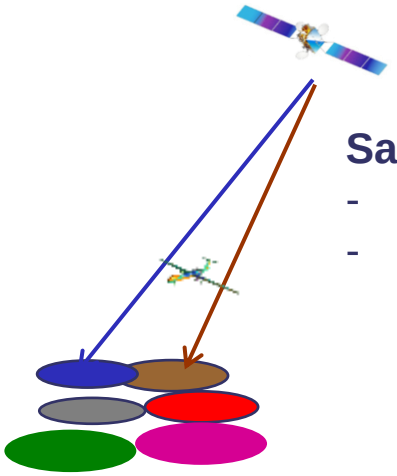
# The 5GHz Solution – Typical Session

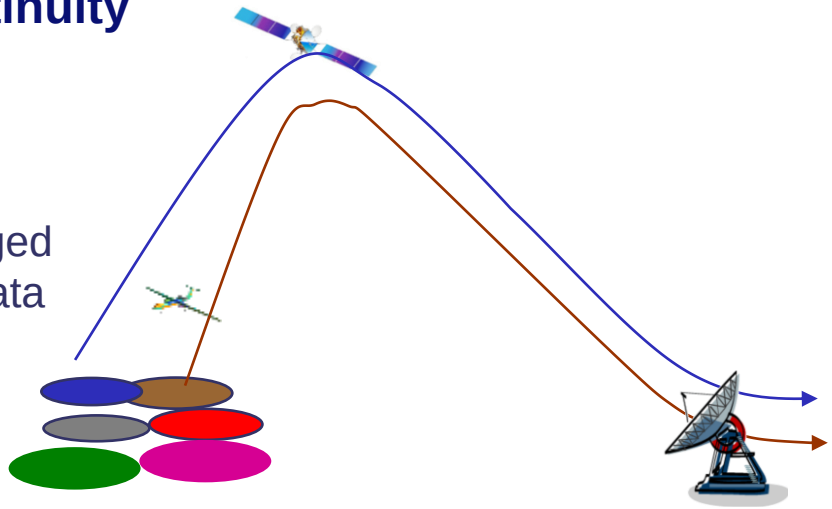


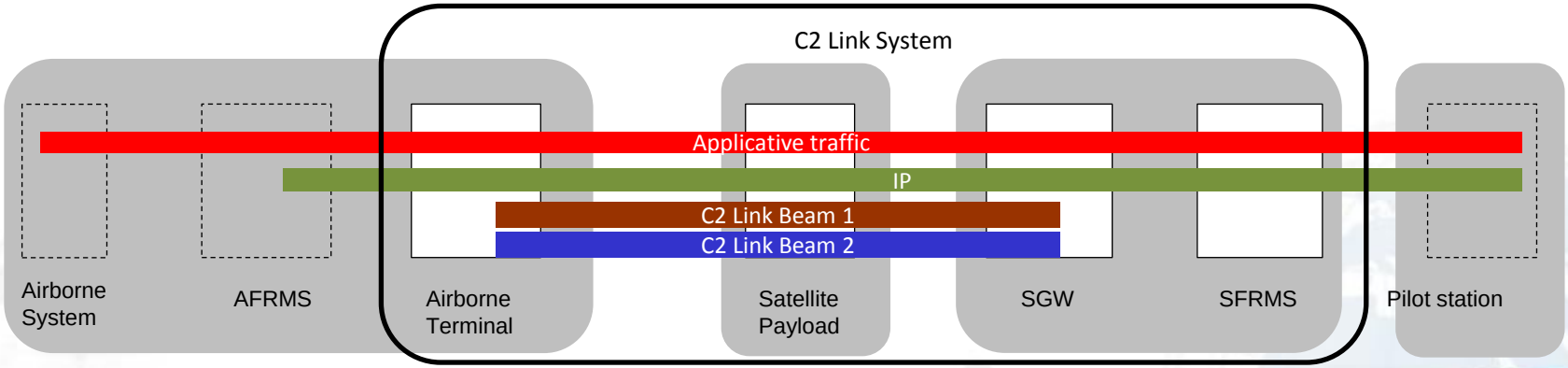
- **Seamlessly, as the RPAS progresses on the coverage, handover(s) takes place to ensure continuity**



**Satellite Beam Handover**

- RX and TX carriers are changed
- Transparent for end-to-end data



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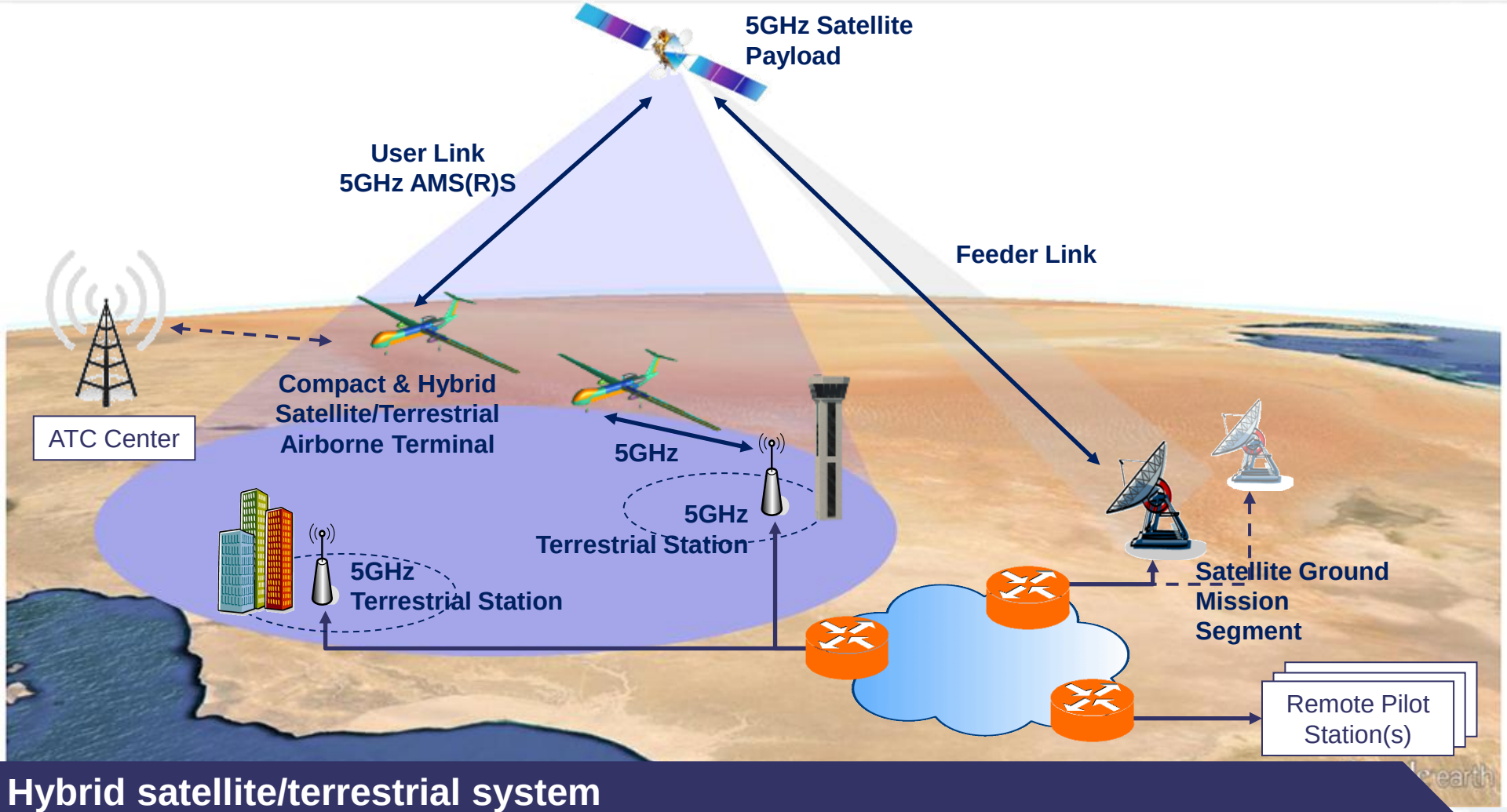
# The 5GHz Solution – Key Advantages



- **Exclusive and global allocation to civil aviation services: AMS(R)S**
- **Unique standards applicable worldwide**
  - ➔ **RTCA DO-362 (and upcoming update) for the Terrestrial Component**
  - ➔ **EUROCAE upcoming ED-XX for Satellite Component**
- **System capacity compatible with mid/long term needs**
- **Hybrid terrestrial/satellite airborne terminal**
  - ➔ Satellite connectivity without any additional hardware
  - ➔ 5GHz is currently in some places the only option for the terrestrial link (e.g. in Europe)
  - ➔ Possible integration in a **dual use terminal** (Civil 5GHz + NATO 4.4-4.9 GHz)
    - ➔ single equipment for military and civil airspace
- **Small antenna footprint and no accommodation constraint**
  - ➔ compatibility with light drones (<150 kg)
- **Simple system delivering high level safety performances**

# The 5GHz Solution – Overall Architecture






**Hybrid satellite/terrestrial system**
**Large coverage area ensuring very high safety performance where needed**

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