Challenges to Aviation Spectrum usage

April 2021

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Spectrum Management

- What are we talking about here ?
  - Goal of spectrum management is to minimize interference and ensure that the identified frequencies are used in an efficient and effective manner for the benefit of the public.
- Spectrum Stakeholders in the US:
  - FCC
  - NTIA
  - FAA
- International Spectrum Co-ordination takes place via the ITU
  - WRC (World Radiocommunication Conference) – 4 year cycle – 2023 (https://www.itu.int/en/ITU-R/conferences/wrc/Pages/default.aspx)
  - For aviation (in specific) it takes place through ICAO FSMP (Frequency Spectrum Management Panel)
- Other national spectrum bodies that play a key role in shaping spectrum regulation
  - OFCOM (UK), ANFR (France)

Aviation Spectrum Compatibility Concerns

- GPS and Ligado
- Iridium and Ligado
- Radar altimeter and 5G systems
- Aeronautical VHF Data link and new VHF Satcom
- DME and LDACS
- 94 GHz EFVS and FOD Radars
- UAS C2 and Aeromacs

- There are other additional issues that are being tracked across industry where UWB poses potential concerns for multiple systems including VHF and Radar altimeters
- Aviation is supportive of 5G. However, additional effort is needed to ensure that 5G/LTE/IMT systems are compatible with aviation safety of life systems and applications.

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C-BAND

FCC REALLOCATION PLAN

- Current allocations
  - 3.7 – 4.2 GHz (C-Band): Satellite Spectrum
  - 4.2 – 4.4 GHz: Aeronautical Radionavigation (Aviation Safety equipment)
- FCC's reallocation could have direct impacts on the safe operation of flight
  - 3.7 – 3.98: 5G
  - 4.0– 4.2: Satellites
  - 4.2 – 4.4: Aeronautical Radionavigation

High likelihood for additional spectrum sales around the radar altimeter band outside US

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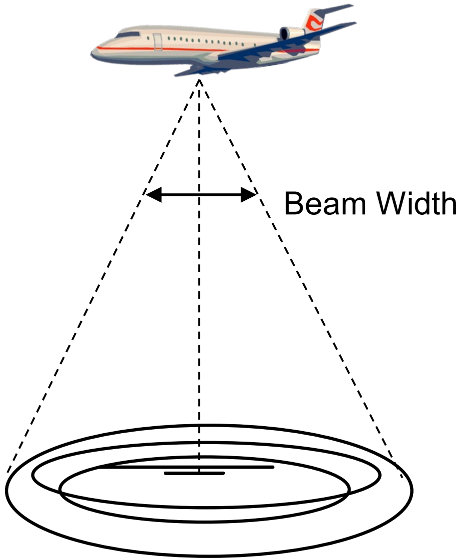
TIMELINE

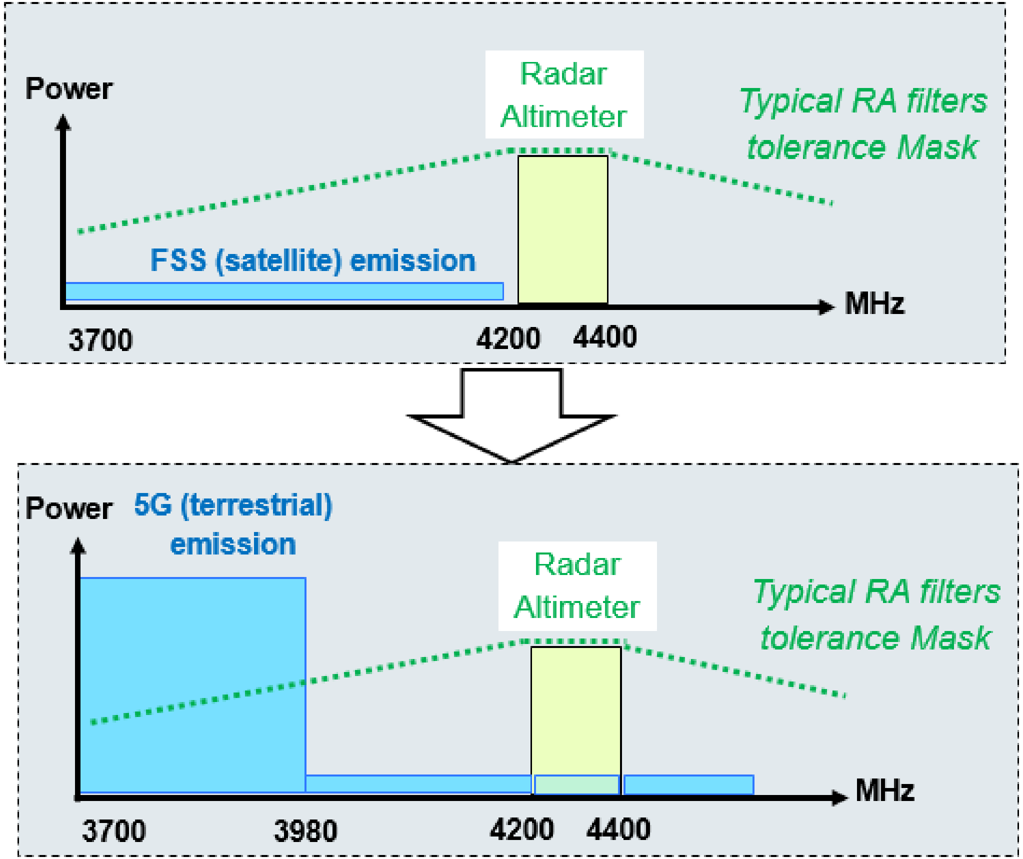
KNOWN AND EXPECTED MILESTONES

- FCC Spectrum Auction : Completed in Jan ’21. Raises $81+ bn for US treasury
- RTCA SC-239 formed to address 5G impacts to LRRA
  - Assessment of C-Band Mobile Telecommunications Interference Impact on Low Range Radar Altimeter Operations
- Spectrum relocation date:
  - Accelerated spectrum relocation (with financial incentives to space station operators):
    - Phase 1 (3.7 – 3.8 GHz) spectrum clearing date: Dec 5, 2021
    - Phase 2 (3.8 – 4.0 GHz) spectrum clearing date: Dec 5, 2023

Pictorial of the radar altimeter operation



RTCA Report Context



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5G Base Station characteristics - 8 by 8 AAS arrays

Table 6-3: 5G Base Station Characteristics[13] for 8 x 8 AAS Arrays

Environment	Urban	Suburban	Rural
Antenna Pattern	ITU-R M.2101-0	ITU-R M.2101-0	ITU-R M.2101-0
Array Size	8 x 8	8 x 8	8 x 8
Element Gain	6.4 dBi	7.1 dBi	7.1 dBi
Element Horizontal 3 dB Beamwidth	90 degrees	90 degrees	90 degrees
Element Vertical 3 dB Beamwidth	65 degrees	54 degrees	54 degrees
Front-to-Back Ratio	30 dB	30 dB	30 dB
Horizontal Array Spacing Coefficient	0.5	0.5	0.5
Vertical Array Spacing Coefficient	0.7	0.9	0.9
Vertical Scan Range[14]	-30 to 0 degrees	-10 to 0 degrees	-10 to 0 degrees
Peak Array Gain	24.5 dBi	25.2 dBi	25.2 dBi
Mechanical Downtilt[15]	10 degrees	6 degrees	3 degrees
Mast Height	20 meters	25 meters	35 meters
Downlink Bandwidth	100 MHz	100 MHz	100 MHz
Activity Factor	50%	50%	50%
Conducted Power per Element	25 dBm	25 dBm	25 dBm
Peak Output EIRP	67.5 dBm	68.2 dBm	68.2 dBm
Peak Output PSD (EIRP)[16]	47.5 dBm/MHz	48.2 dBm/MHz	48.2 dBm/MHz
Conducted PSD, Spurious	-20 dBm/MHz	-20 dBm/MHz	-20 dBm/MHz
Peak Output PSD, Spurious (EIRP)[17]	-13.6 dBm/MHz	-12.9 dBm/MHz	-12.9 dBm/MHz

5G Base station characteristics – 16 by 16 AAS arrays

RTCA
THE GOLD STANDARD FOR AVIATION SINCE 1935

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Urban AAS Base station Patterns

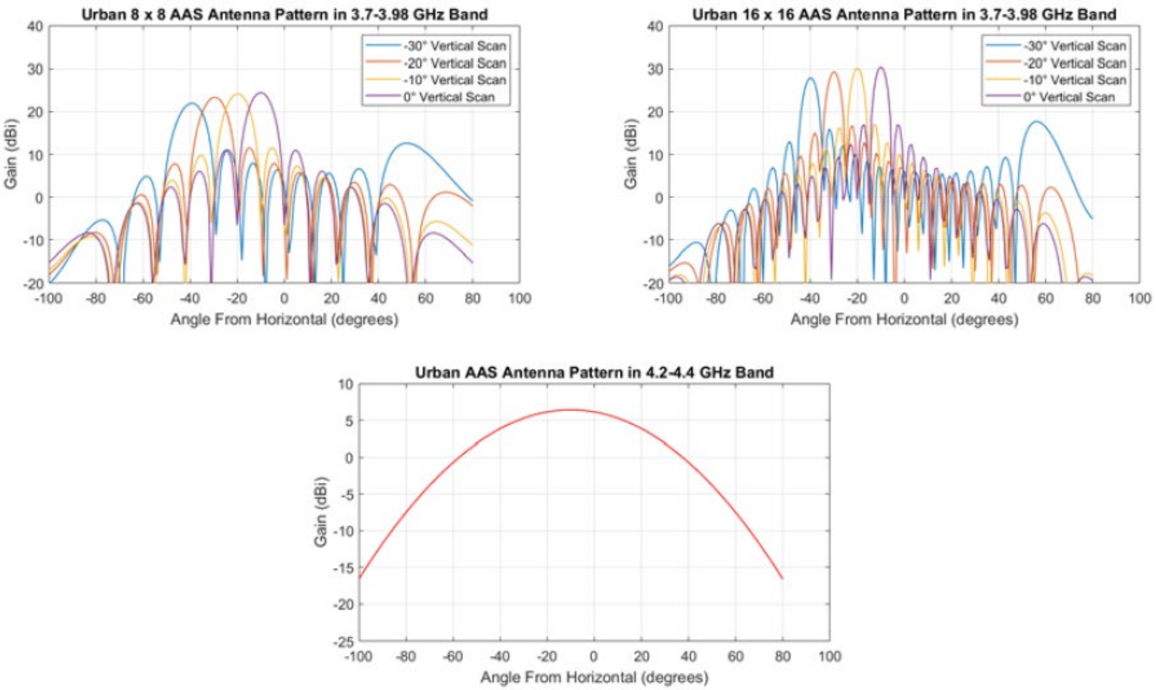
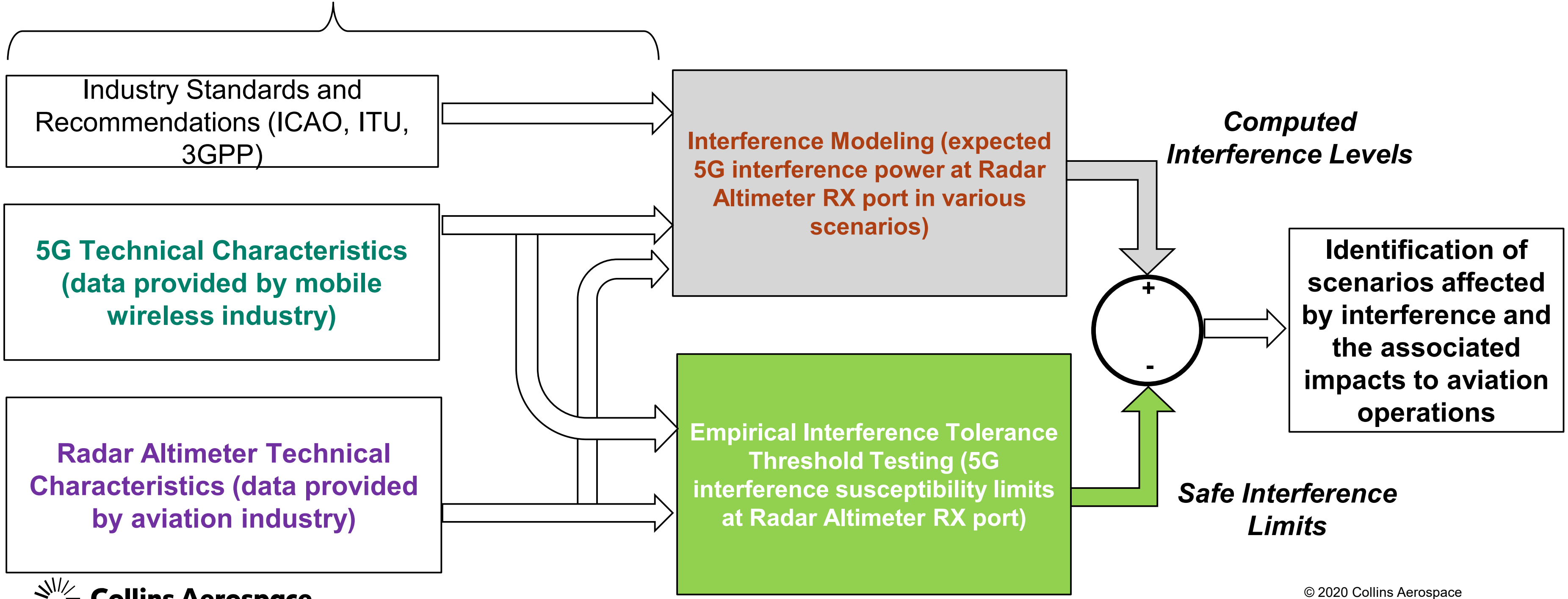


Figure 6-4: Antenna Pattern Elevation Plane Cuts for Urban AAS Base Stations

RTCA Report Methodology

RTCA interference analysis considers inputs from applicable industry standards, recommendations, and regulations. Additional technical characteristics and assumptions were based on inputs received from both the mobile wireless and aviation industries.



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RTCA Report Results

Red dots mean that the safe interference limit is exceeded

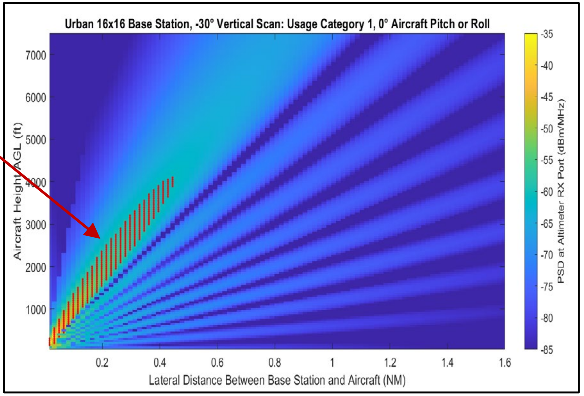
For Usage Category 1 (commercial airplanes used for passenger travel and cargo transport):

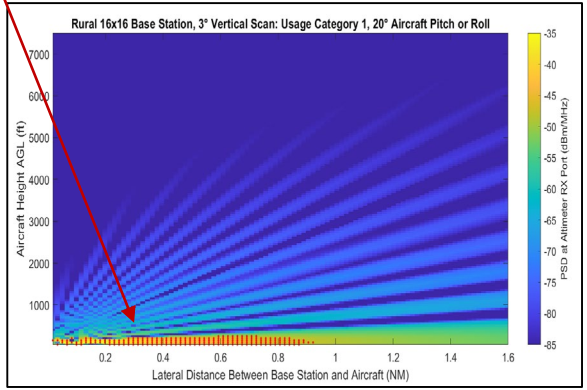
LIMITED NUMBER OF 5G SCENARIOS INVOLVED

The impact to Radar Altimeters is limited to a set of specific scenarios, with only some base station configurations producing interference above the safe limit, and only for certain combinations of aircraft altitude and lateral distance between the aircraft and base station.

BUT EXTREME IMPACT ON AIRCRAFT

Although the interference impacts for Usage Category 1 only arise in certain scenarios, the extent and safety consequences of those impacts are extreme. Catastrophic impact with the ground, leading to multiple fatalities, is possible.





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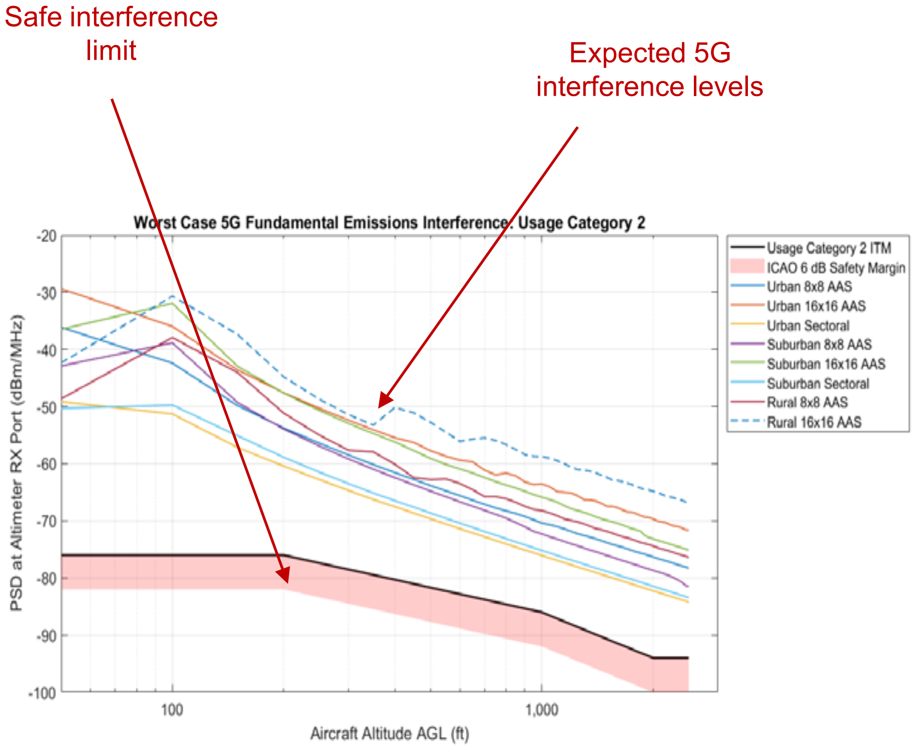
RTCA Report Results

For Usage Category 2 (business aviation, general aviation, and regional transport airplanes) and Usage Category 3 (both transport and general aviation helicopters):

HUGE AMOUNT OF SCENARIOS INVOLVED
Every base station configuration produces harmful interference both from 5G fundamental emissions in the 3.7–3.98 GHz band and 5G spurious emissions in the 4.2–4.4 GHz band, across virtually all operational scenarios and relative geometries between the aircraft and base station.

5G user equipment that may be operating onboard aircraft were also found to exceed the safe interference limits for Usage Categories 2 and 3.



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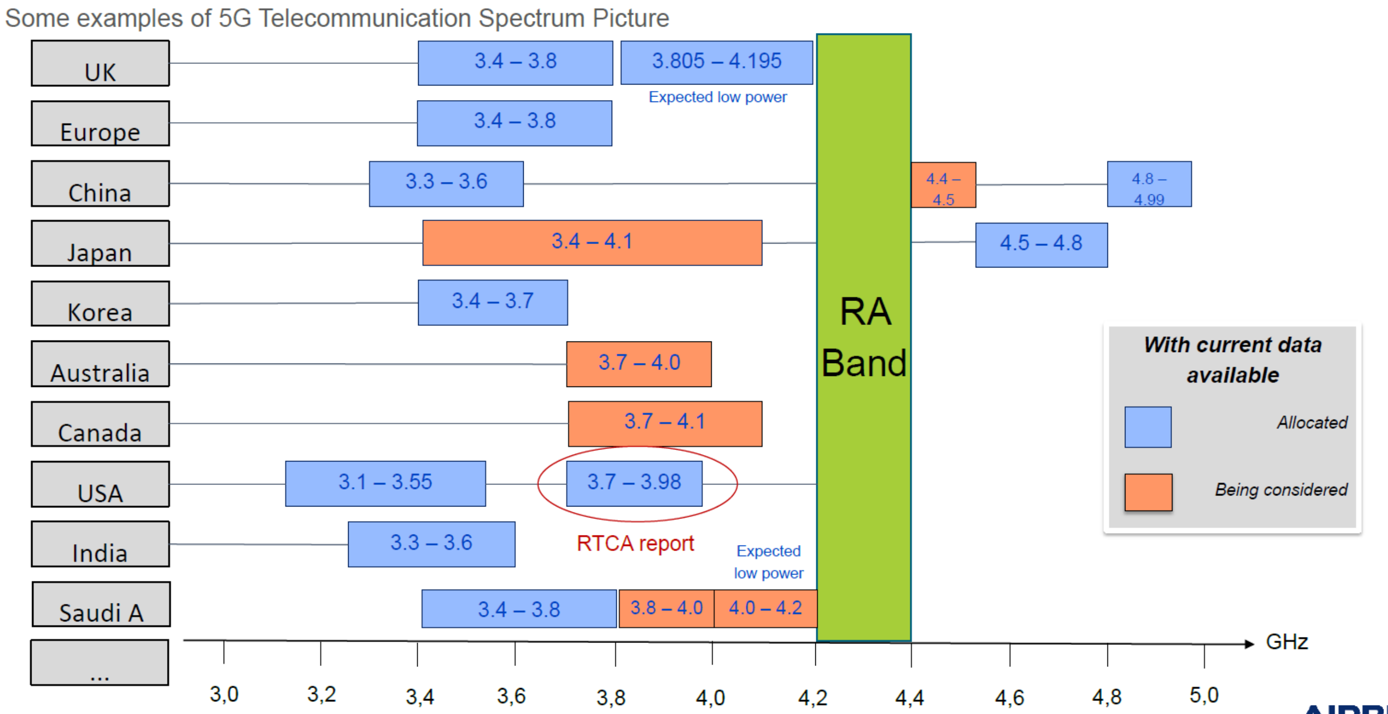
Impacts due to loss of/erroneous rad alt function

- Passengers, crews, and aircraft are at risk because automatic landing and collision avoidance systems depend on inputs coming direct from the altimeter. Incorrect or no measurements could cause an aircraft to prematurely deploy landing systems or incorrectly adjust flight systems.
- If a medevac helicopter cannot safely land either at a hospital or accident location (e.g., a highway traffic accident) due to interference to the altimeter from 5G deployments, then operations will have to cease. The lives of pilots, other emergency services personnel, and passengers are at risk.
- In inclement weather where visibility is significantly reduced, pilots will have a more difficult time landing and could be prevented from safely guiding the aircraft to the ground.

Interference to radar altimeters could endanger safety of life airborne operations

World View of Future 5G Spectrum Reallocation



AIRBUS

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Continuing efforts

- Aviation Industry is working towards updating the radar altimeter performance standards - ECD ’23
    - *This will not help currently fielded solutions*
    - *It will take 5-10 years to design, develop and field radar altimeters that meet the new standards*
- Given the short time frame for 5G rollout, mitigations need to be adopted by 5G systems:
    - Aviation has filed technical recommendations on 5G mitigations with FCC to protect radar altimeter function
- Issue has been discussed at ICAO and this has generated an ICAO state letter.
- EASA is in discussions with industry to assess impact to radar altimeters and airborne operations.

As 5G is expected to begin operating as soon as the end of 2021, action must be taken now to ensure aviation use of radar altimeters remain safe.

BACKUP SLIDES

Aircraft level impacts due to loss of radar altimeter function

scenario	Event on Radio Altimeters	Impact on aircraft	Flight Phase	Criticality per RA (maximum occurrence per flight hour)
1	Undetected Erroneous Radio Altimeter value	At the last phase of landing (when the aircraft is physically below 50ft), aircraft needs to perform a flare operation in order to avoid a hard landing. This operation can be done manually by the crew or automatically. Autoland operations require it's use in very low visibility conditions. A typical ILS approach requires a descent rate of approximately 900 Feet per Minutes. If the “FLARE” mode fails to engage at 50 ft during an auto land, the aircraft would make ground contact in roughly 3 seconds. Given that some CAT III approaches are conducted with an alert height and do not require visual ground reference for landing, an untimely failure in this phase of operation would provide little to no time for pilot reaction and recovery.	Flare	10-9 /fh (derived from AC 120-28D)
2	Undetected Erroneous Radio Altimeter value	Wrong input in the automated flight systems could affect the aircraft attitude command and altitude as well as flight control protection mechanisms	All phases of flight	10-9 /fh (derived from AC 120-28D)
3	Loss of Radio Altimeters (i.e Non Computed Data)	Loss of PWS (Predictive Wind Shear) Also loss of RA on Display does affect flight aircrew awarness of Wind shear impact to vertical profile. Not impacted by atmospheric effect (unlike AoA) important/key instrument for the crew to understand the windshear event and react appropriately.	landing	10-7 /fh
4	Loss of Radio Altimeters (i.e Non Computed Data)	Undetected loss of TCAS (Traffic Collision Avoidance System) inhibition near the ground : Example: If the RA (radio altimeter) falls in NCD (non Computed Data) state while the aircraft is close to ground the TCAS II/ACAS Xa/Xo can command a descent advisory order due to an incursion of adjacent traffic. The procedure is to comply with the TCAS II/ACAS Xa/Xo even if ATC issued a climb or level off. This situation can create a risk of CFIT (Controlled Flight Into Terrain). When the RA is performed automatically (directly coupled to the Auto Pilot), the risk of CFIT becomes higher especially in low visibility conditions. TCAS II/ACAS Xa/Xo derived from RTCA-DO-185()/-385.	Approach, Landing and TO	10-7 /fh

Aircraft level impacts – page 2/2

5	Undetected Erroneous Radio Altimeter value	Erroneous or erratic RA indications could lead to the risk of triggering an RA TAWS reactive terrain avoidance manoeuver command that must be complied with by the pilots. This subsequent aggressive escape manoeuver can lead to a traffic conflict in IMC condition. This ground escape manoeuver gets the priority over a potential avoidance traffic resolution advisory to avoid the traffic collision.	Approach, Landing and TO	10-5 /fh
6	Loss of Radio Altimeters (i.e Non Computed Data)	Risk of a Go Around as landing guidance laws are affected. Notice that the safety of the Airspace is also jeopardized especially if several aircraft are affected	Approach and Landing	10-5 /fh
7	Loss of Radio Altimeters (i.e Non Computed Data)	Loss of the capability approach in low visibility conditions leading to aircraft diversion. Notice that the safety of the Airspace is also jeopardized especially if several aircraft are affected	All phases of flight	10-5 /fh
8	Loss of RA (i.e Non Computed Data)	Loss of safety net in case of CFIT (Controlled Flight Into Terrain) : loss of the capability to warn the crew in case of excessive descent rate or excessive closure rate with the terrain. Derived from RTCA DO-161A (mode 1 and 2) TAWS (Terrain Awarness System)	All phases of flight	10-5 /fh
9	Loss of Radio Altimeters (i.e Non Computed Data)	Loss of Safety Net in case of CFIT (Controlled Flight Into Terrain). Loss of the capability to warn the crew of potential hazardous loss of height after take-off. Derived from DO-161A (mode 3). TAWS (Terrain Awarness System). For instance: at low altitude (200ft), pitch and roll can be significant during the Go Around. There are many criteria on takeoff and GA that are predicated on RA altitude. For instance lateral modes can be activated on the basis of RA. In instances where an immediate turn is critical due to terrain or airspace constraints, even a slight delay in that turn could be highly problematic.	Take off and Go around	10-5 /fh
10	Loss of Radio Altimeters (i.e Non Computed Data)	Loss of Safety Net : loss of capability to warn the crew of potential hazardous aircraft height when not in a correct landing configuration (L/G, slap, flap). This alert is derived from DO-161A (mode 4) TAWS (Terrain Awarness System)	Landing	10-5 /fh
11	Loss of Radio Altimeters (i.e Non Computed Data)	Loss of Safety Net in case of CFIT (Controlled Flight Into Terrain) : Loss of the capability to warn the crew that the aircraft is dangerously below the glide path during a precision approach (ILS or ILS-like approach). Mode 5 protection never activates due to lack of an altitude reading from the radio altimeter. This alert is derived from DO-161A (mode 5) TAWS (Terrain Awarness System)	Landing	10-5 /fh
12	Loss of Radio Altimeters (i.e Non Computed Data)	Loss of safety net: loss of flight crew call outs (that are predicated on RA altitudes) which support situational awareness and assists in stabilizing the approach and landing. Could lead to confusion and distraction in a very critical phase of flight	Approach, Landing, Flare	10-3 /fh