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Demystifying EMC 2023 virtual conference

# SATELLITE EMC TESTING



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Technical Sales  
Automotive and Military EMC Test system

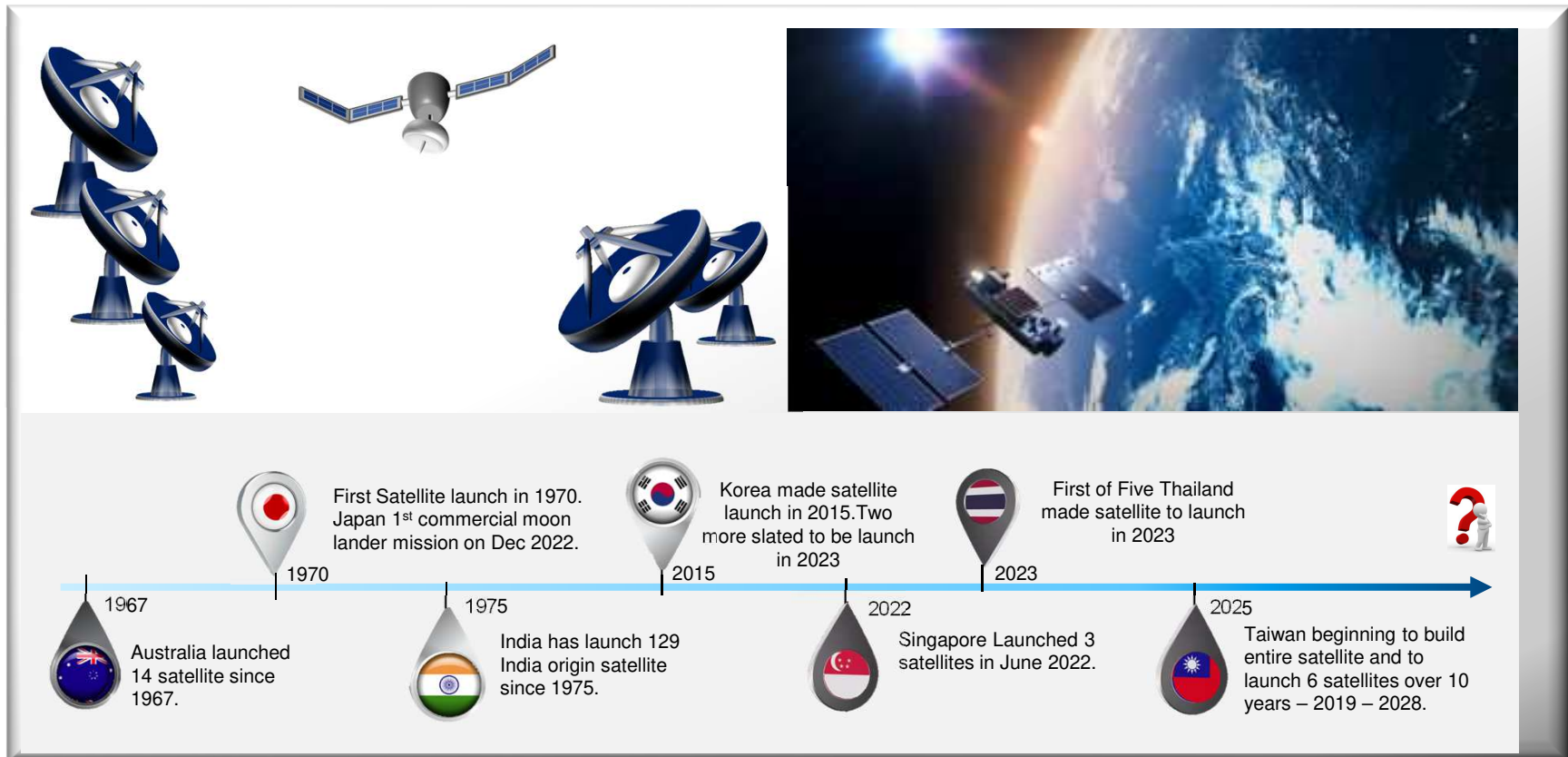
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# SATELLITE – MADE IN ASIA



# EMC STANDARDS BASED ON EUT

▶ Different Electronic Equipment require compliance to different Standards

## Commercial Equipment:

- | ISM Equipment
- | Consumer Electronics Equipment
- | IT / Household Equipment
- | Lighting Equipment

## Applicable Standards:

- | CISPR 11 - 35
- | IEC61000-X-X series
- | Product Specific Standards



## Military Equipment:

- | Aircraft Equipment
- | Ship & Submarine Equipment
- | Land Based Equipment

## Applicable Standards:

- | Mil-Std 461
- | Mil-Std 464C
- | GJB151A/152A-97



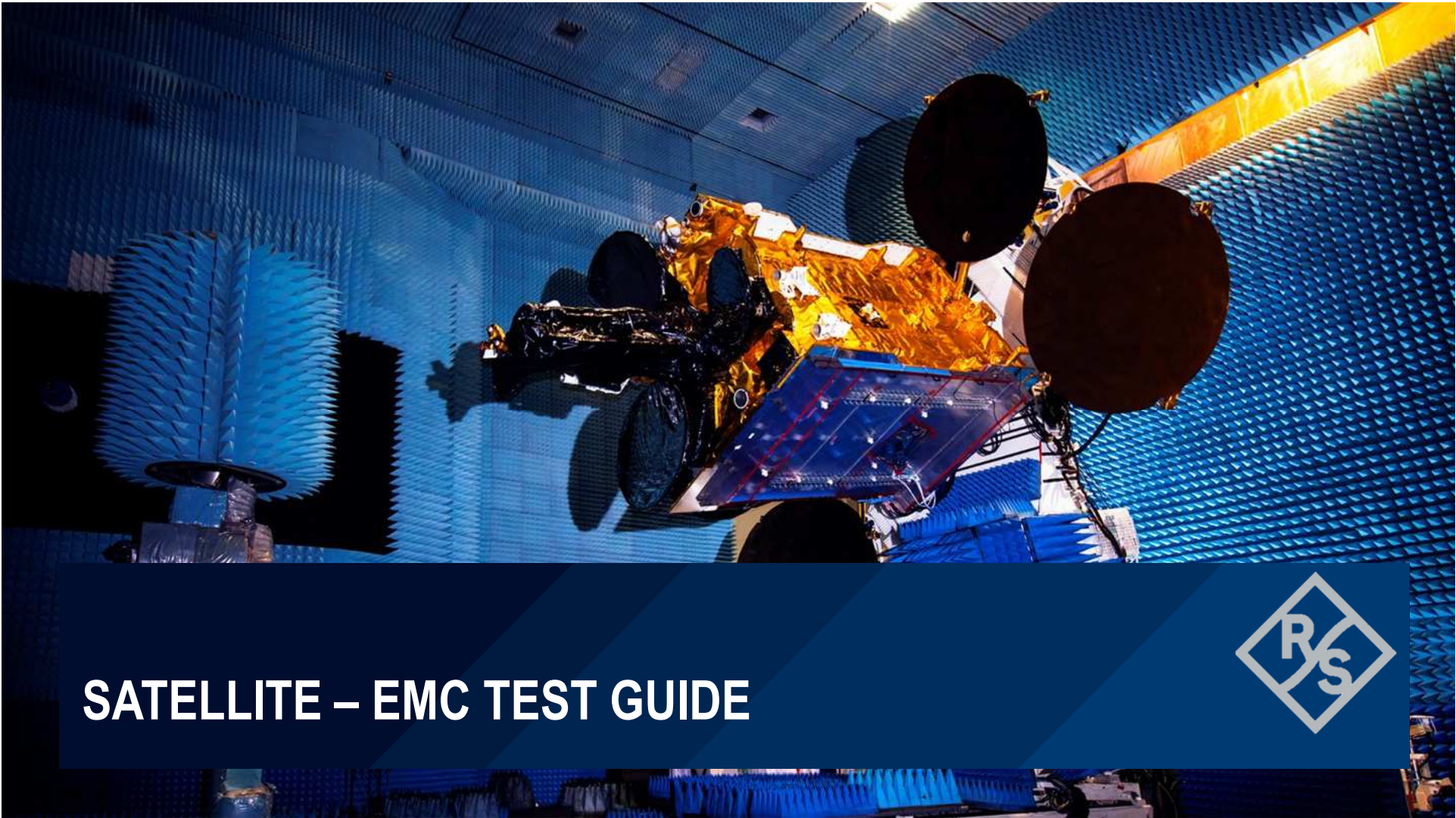
## Automotive Equipment:

- | Control Equipment
- | Infotainment Equipment
- | Communication Equipment

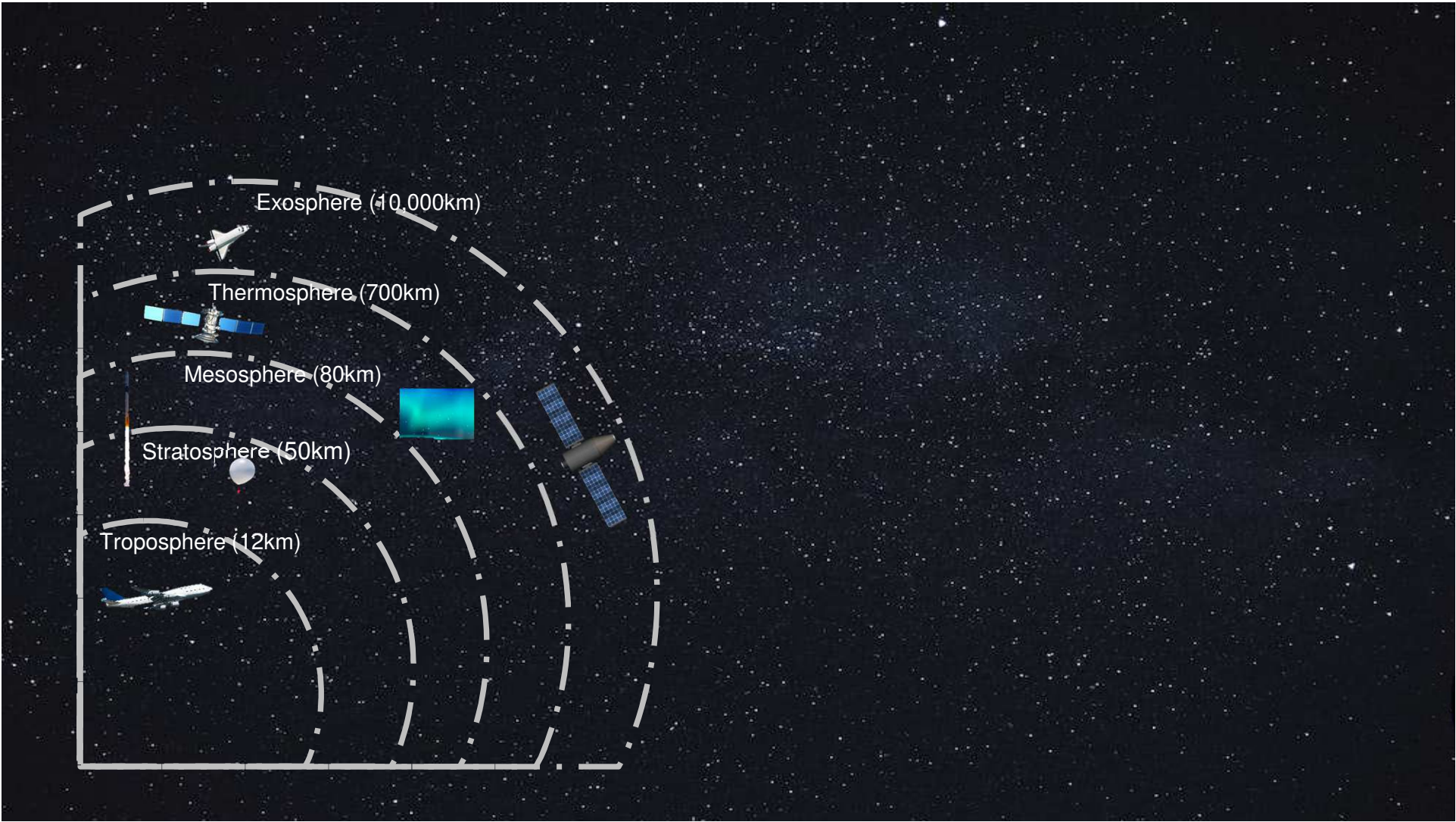
## Applicable Standards:

- | CISPR 12, 25
- | ISO11451, ISO11452
- | Product Specific Standards



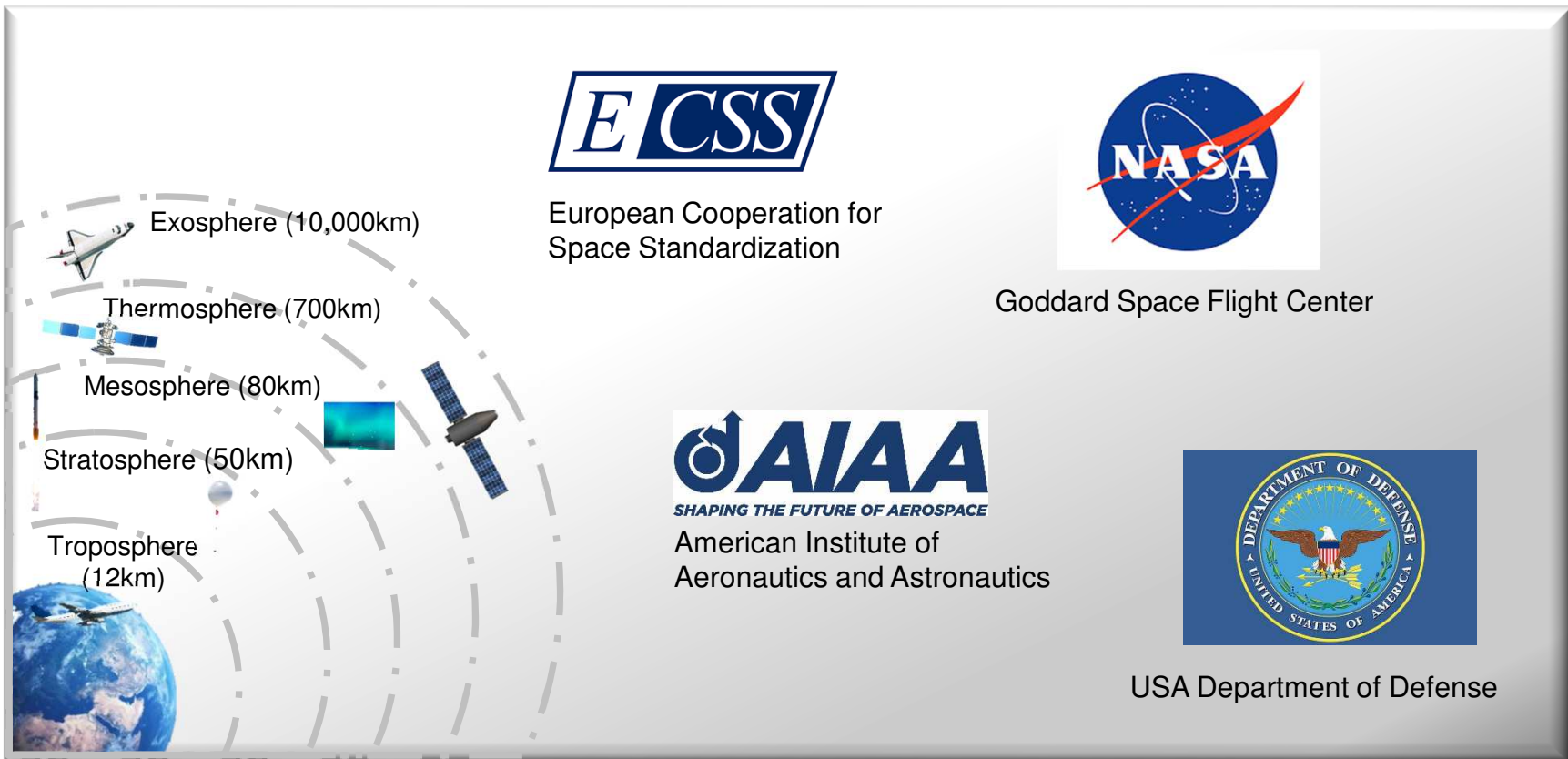


# SATELLITE – EMC TEST GUIDE



# EMC STANDARDS BASED ON EUT

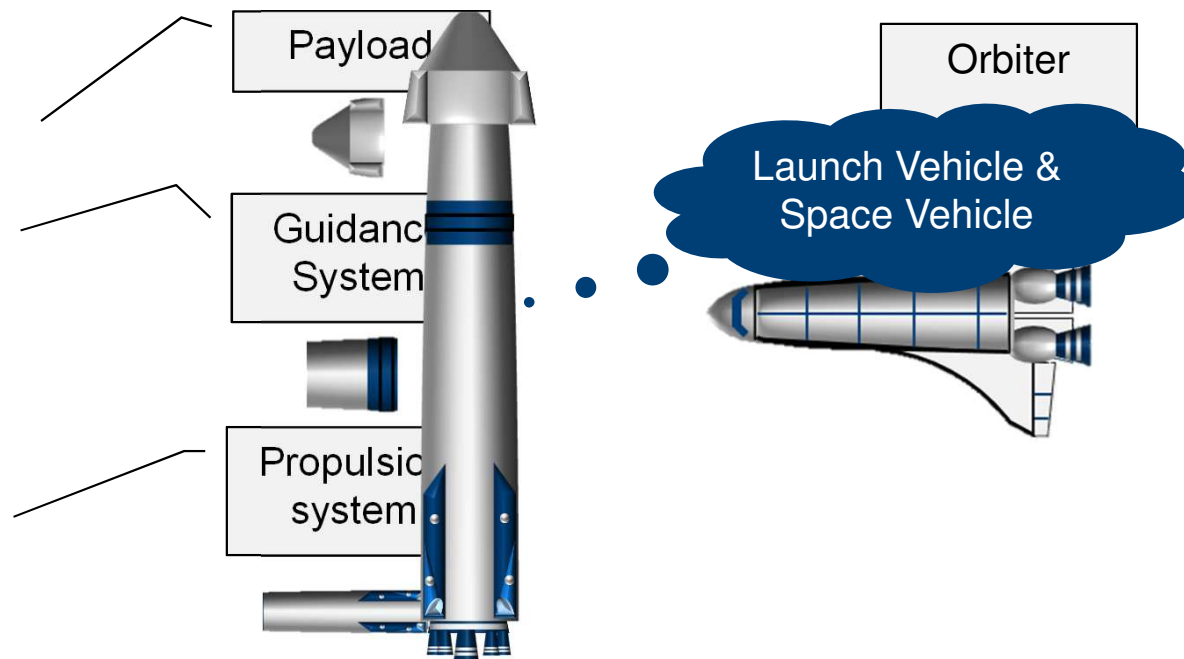
► Different Standards and EUT are drafted based on operating environment



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# PARTS OF SATELLITE ROCKET

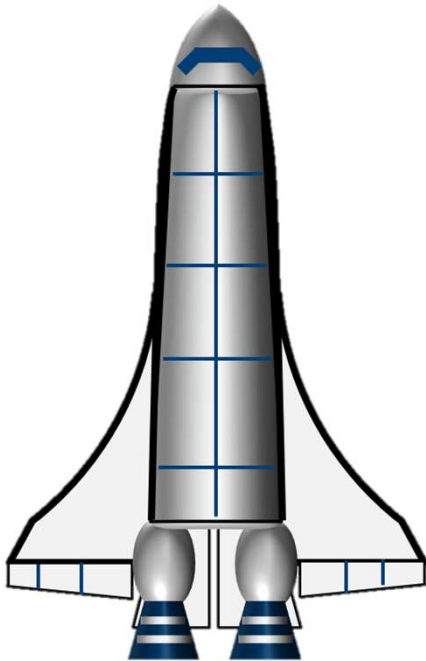




# PURPOSE

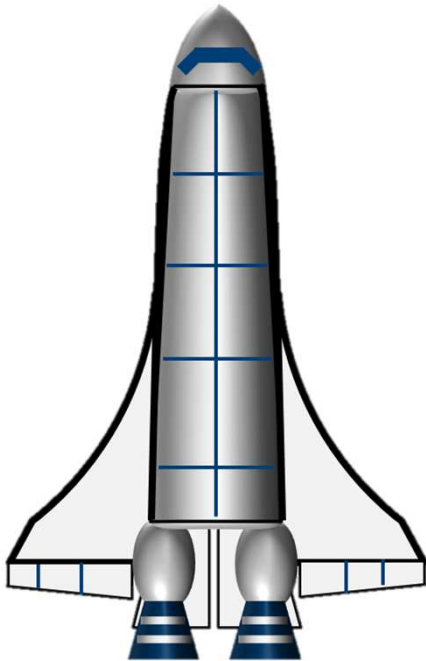
- ▶ Ensuring space systems **system level** electromagnetic compatibility (EMC), for all **Intersystem and Intra-system** including all **electromagnetic environmental effects**.
- ▶ Guidelines for environmental verification programs for **payloads, subsystems and components**. Through **baseline test and/or analysis** and that minimum workmanship standards have been met.
- ▶ Gives **guideline test levels**, provides guidance in the choice of test options, and describes **acceptable test and analytical methods** for implementing the requirements.

# MIL-STD461G APPLICABLE TO SPACE SYSTEMS



| MIL-STD 461 G |             |  |                    |                            |
|---------------|-------------|--|--------------------|----------------------------|
| S/N           | Requirement | Description  | Frequency          | Space System Applicability |
| 1             | CE101       | Conducted Emissions, Audio Frequency Currents, Power Leads                     | 30Hz to 10kHz      | -                          |
| 2             | CE102       | Conducted Emissions, Radio Frequency Potentials, Power Leads                   | 10kHz to 10MHz     | A                          |
| 3             | CE106       | Conducted Emissions, Antenna Port  | 10kHz to 40GHz     | L                          |
| 4             | CS101       | Conducted Susceptibility, Power Leads  | 30Hz to 150kHz     | A                          |
| 5             | CS103       | Conducted Susceptibility, Antenna Port, Intermodulation                        | 15kHz to 10GHz     | S                          |
| 6             | CS104       | Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals         | 30Hz to 20GHz      | S                          |
| 7             | CS105       | Conducted Susceptibility, Antenna Port, Cross-Modulation                       | 30Hz to 20GHz      | S                          |
| 8             | CS109       | Conducted Susceptibility, Structure Current                                    | 60Hz to 100kHz     | -                          |
| 9             | CS114       | Conducted Susceptibility, Bulk Cable Injection                                 | 10kHz to 200MHz    | A                          |
| 10            | CS115       | Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation             | Impulse Excitation | A                          |
| 11            | CS116       | Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads | Transient          | A                          |
| 12            | CS117       | Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads | Transient          | L                          |
| 13            | CS118       | Conducted Susceptibility, Personnel Borne Electrostatic Discharge              | Transient          | -                          |
| 14            | RE101       | Radiated Emissions, Magnetic Field   | 30Hz to 100kHz     | -                          |
| 15            | RE102       | Radiated Emissions, Electric Field   | 10kHz - 18GHz      | A                          |
| 16            | RE103       | Radiated Emissions, Antenna Spurious and Harmonic Outputs                      | 10kHz - 40GHz      | L                          |
| 17            | RS101       | Radiated Susceptibility, Magnetic Field  | 30Hz to 100kHz     | -                          |
| 18            | RS103       | Radiated Susceptibility, Electric Field  | 2MHz - 40GHz       | A                          |
| 19            | RS105       | Radiated Susceptibility, Transient Electromagnetic Field                       | Transient          | -                          |

# AIAA APPLICABLE TO SPACE SYSTEMS (EMC)



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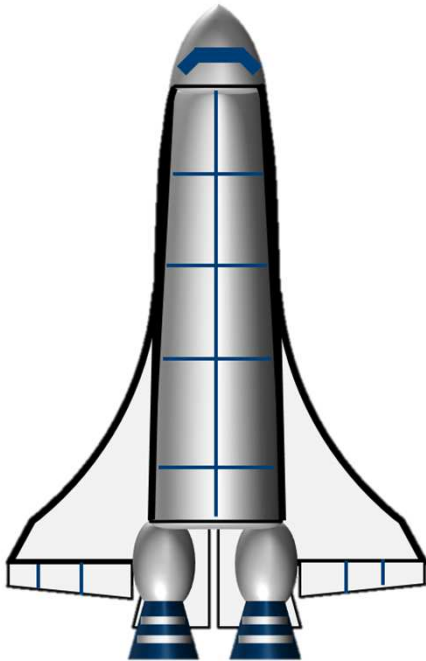
| AIAA ( Table 6 Requirement Applicability Matrix) |             |   |                |                |                                      |                  |
|--|-------------|---|----------------|----------------|--------------------------------------|------------------|
| S/N  | Requirement | Description   | Frequency      | Launch Vehicle | Space Vehicle systems and subsystems | Ground Equipment |
| 1  | 8.4.1       | Power Bus conducted Interference , load induced, audio frequency                    | 30Hz - 150kHz  | A              | A                                    | S                |
| 2  | 8.4.2       | Power Bus conducted Interference , load induced, audio frequency                    | 150kHz - 20MHz | A              | A                                    | S                |
| 3  | 8.5         | RF common mode conducted emissions, power and signal cables                         | 150kHz - 20MHz | A              | A                                    | S                |
| 4  | 8.6         | Conducted Emission, Antenna Terminal  | 10kHz - 40GHz  | L              | L                                    | S                |
| 5  | 8.7         | Conducted Emission, Differential Mode, Time Domain, Load Induced Voltage Transients | Transients     | A              | A                                    | S                |
| 6  | 8.8         | Audio Frequency Conducted Susceptibility, Power leads                               | 30Hz - 150kHz  | A              | A                                    | S                |
| 7  | 8.9         | Audio Frequency Conducted Susceptibility, Antenna Port, Intermodulation             | 15kHz - 10GHz  | S              | S                                    | S                |
| 8  | 8.10        | Conducted Susceptibility, Antenna Port, Rejection of undesired Signals              | 30Hz - 20GHz   | S              | S                                    | S                |
| 9  | 8.11        | Conducted Susceptibility, Antenna Port, Cross-Modulation                            | 30Hz - 20GHz   | S              | S                                    | S                |
| 10   | 8.12        | Conducted Susceptibility, Bulk Current Injection, Swept Frequency                   | 10kHz - 200MHz | A              | A                                    | S                |
| 11   | 8.13        | Conducted Susceptibility, Bulk Current Injection, Excitation                        | Impulses       | S              | S                                    | S                |
| 12   | 8.14        | Conducted Susceptibility, Damped Sinusoidal Transients                              | 10kHz - 100MHz | A              | A                                    | S                |
| 13   | 8.15        | Conducted Susceptibility, Ground Plane Injection Spike                              | Spikes         | A              | A                                    | S                |
| 14   | 8.16        | Conducted Susceptibility, Ground Plane Injection, Audio Frequency                   | 30Hz - 150kHz  | A              | A                                    | S                |
| 15   | 8.17        | Conducted Susceptibility, Ground Plane Injection, Radio Frequency                   | 150kHz - 100MH | A              | A                                    | S                |
| 16   | 8.18        | Susceptibility to switching Transients, Power leads, Time Domain                    | Transients     | A              | A                                    | S                |
| 17   | 8.19        | Radiated Emission, Magnetic Field   | 30Hz - 100kHz  | S              | S                                    | S                |
| 18   | 8.20        | Radiated Emission, Electric Field   | 20MHz - 18GHz  | A              | A                                    | S                |
| 19   | 8.21        | Radiated Susceptibility, Magnetic Field   | 30Hz - 100kHz  | L              | L                                    | S                |
| 20   | 8.22        | Radiated Susceptibility, Electric Field   | 2MHz - 18GHz   | S              | S                                    | S                |
| 21   | 8.23        | Radiated Emission, Magnetic Field   | 30Hz - 100kHz  | A              | A                                    | S                |
| 22   | 8.24        | Conducted Susceptibility, Lightning Induced Transients, cables and power leads      | Transients     | L              | L                                    | S                |
| 23   | 8.25        | Electrostatic Discharge Susceptibility, Personnel Borne                             | Transients     | L              | L                                    | S                |

| Applicability ( Table 1 EMI Safety Margin)  | Test (dB) | Analysis (a), (dB) |
|---|-----------|--------------------|
| Category I or II critical circuits (ref. Sect.4.2)                                    | 6         | 12                 |
| EID interfaces, RF level referenced to DC no fire (b)                                 | 20        | 20                 |
| EID interfaces, RF level referenced to RF no fire (c, d)                              | 12        | 12                 |
| All other equipment, subsystems and systems, including Category III critical circuits | 0         | 0                  |

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# GSFC APPLICABLE TO SPACE SYSTEMS (EMC)



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| GSFC (Table 2.5-2, EMI Requirements Summary) |             |  |                    |                       |                              |
|--|-------------|--|--------------------|-----------------------|------------------------------|
| S/N  | Requirement | Description  | Frequency          | Limits                | Test Methods                 |
| 1  | CE101       | Conducted Emissions, Audio Frequency Currents, Power Leads                     | 30Hz to 10kHz      | Tailored              | DM                           |
| 2  | CE102       | Conducted Emissions, Radio Frequency Potentials, Power Leads                   | 10kHz to 10MHz     | Tailored              | CE03, DM, MIL462             |
| 3  | <b>NEW</b>  | Conducted Emissions, Common Mode Power and Signal Lines                        | 10kHz - 200MHz     | NEW                   | NEW                          |
| 4  | <b>NEW</b>  | Conducted Emissions, Turn-on Transient   | Transients         | NEW                   | NEW                          |
| 5  | CE106       | Conducted Emissions, Antenna Terminal  | 200MHz - 18GHz (a) | Tailored              | No Change                    |
| 6  | CS101       | Conducted Susceptibility, Power Leads  | 30Hz to 150kHz     | Tailored              | Alt. Test method available   |
| 7  | CS103       | Conducted Susceptibility, Antenna Port, Intermodulation                        | 15kHz to 10GHz (b) | Tailored              | No Change                    |
| 8  | CS104       | Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals         | 30Hz to 20GHz (b)  | Tailored              | No Change                    |
| 9  | CS105       | Conducted Susceptibility, Antenna Port, Cross-Modulation                       | 30Hz to 20GHz      | N/A                   | N/A                          |
| 10   | <b>CS06</b> | Conducted Susceptibility, Transients, Power Leads                              | Transients         | CS06                  | CS06, MIL462                 |
| 11   | CS109       | Conducted Susceptibility, Structure Current                                    | 60Hz to 100kHz     | N/A                   | N/A                          |
| 12   | CS114       | Conducted Susceptibility, Bulk Cable Injection                                 | 10kHz to 200MHz    | Tailored              | No Change                    |
| 13   | CS115       | Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation             | Impulse Excitation | No Change, Applicable | No Change, Applicable        |
| 14   | CS116       | Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads | Transient          | Applied case by case  | Applied case by case         |
| 15   | CS117       | Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads | Transient          | Applied case by case  | Applied case by case         |
| 16   | CS118       | Conducted Susceptibility, Personnel Borne Electrostatic Discharge              | Transient          | Applied case by case  | Applied case by case         |
| 17   | RE101       | Radiated Emissions, Magnetic Field   | 30Hz to 100kHz     | Tailored              | Alt. RE04, MIL462 available. |
| 18   | RE102       | Radiated Emissions, Electric Field   | 10kHz - 18GHz      | Tailored              | Alt. Test method available   |
| 19   | RE103       | Radiated Emissions, Antenna Spurious and Harmonic Outputs                      | 10kHz - 40GHz      | N/A                   | N/A                          |
| 20   | RS101       | Radiated Susceptibility, Magnetic Field  | 30Hz to 100kHz     | Tailored              | No Change                    |
| 21   | RS103       | Radiated Susceptibility, Electric Field  | 2MHz - 40GHz       | Tailored              | Tailored                     |
| 22   | RS105       | Radiated Susceptibility, Transient Electromagnetic Field                       | Transient          | N/A                   | N/A                          |

Note:

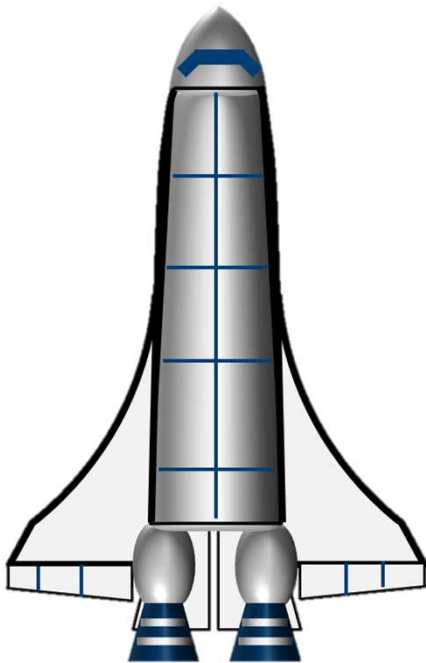
a. Limits and test method shall apply in frequency bands used by other antenna-connected receivers on the platform.

b. Where appropriate, testing may be limited to specific frequency bands used by antenna-connected systems on the spacecraft and launch vehicle.

EMI Safety margin 6dB Ref. MIL-STD-464C, Sect. 5.1

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# ECSS APPLICABLE TO SPACE SYSTEMS (EMC)

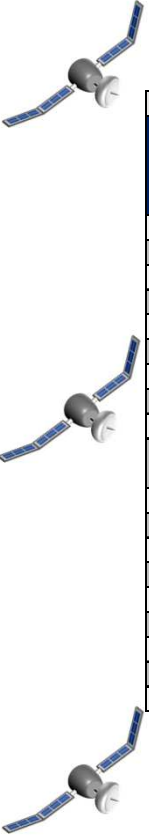


| ECSS (Table 5-4 Correspondence between Test procedures and limits) |             |   |                  |   |
|--|-------------|---|------------------|---|
| S/N  | Requirement | Description   | Frequency        |   |
| 1  | A.2         | CE on power leads, differential mode (Part 1)             | 30Hz - 100kHz    | Limit and Test method provided          |
| 2  | A.2         | CE on power leads, differential mode (Part 2)             | 100kHz - 100 MHz | Limit provided, Test method Ref. to A.4 |
| 3  | A.3         | CE on power leads, in-rush currents                       | Transients       | Limit and Test method provided          |
| 4  | A.4         | CE on power and signal leads, common mode                 | 100kHz - 100 MHz | Limit and Test method provided          |
| 5  | A.6         | DC Magnetic field emission                                | Transients       | NEW                                     |
| 6  | A.7         | RE, low frequency Magnetic field                          | Specific         | Analysis needed                         |
| 7  | A.8         | RE, low frequency Electric field                          | Specific         | Analysis needed                         |
| 8  | A.9         | RE, Electric Field  | 30MHz - 18GHz    | Limit provided. Setup: RE102            |
| 9  | A.10        | CS, power leads, differential mode                        | 30Hz - 100kHz    | Limit and Test method provided          |
| 10   | A.11        | CS, power and signal leads, common mode                   | 50kHz - 100MHz   | Limit and Test method provided          |
| 11   | A.12        | CS, power leads, short spike transients                   | Transients       | Limit and Test method provided          |
| 12   | A.13        | RS, Magnetic field  | 30Hz - 100kHz    | Immunity level provided. Setup: RS101   |
| 13   | A.14        | RS, Electric Fields                                       | 30MHz - 18GHz    | Immunity level provided. Setup: RS103   |
| 14   | A.15        | Susceptibility to Electrostatic Discharge (Legacy method) | Transients       | Legacy and Alternate method specified.  |

EMI Safety margin (EMISM) represented by testing and verifications. Use one or more of the following test approaches:

1. Inject interference at critical system points at x dB higher level than exists, while monitoring other system points for improper responses, where x = EMISM.
2. Measure the susceptibility of critical system circuits for comparison to existing interference levels, to determine the margin.
3. Sensitize the system to render it x dB more susceptible to interference, while monitoring for improper response, where x = EMISM.

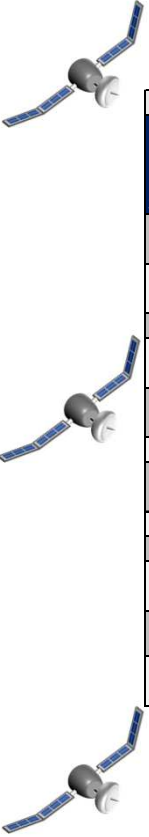
# SPACE SYSTEMS – EMC TEST DIFFERENCES



Comparison Table

| S/N | Description   | Frequency        | Launch Vehicle, Space Vehicle systems and subsystems (AIAA) | Space systems (MIL 461G) | EMI Requirement (GSFC)    | Test procedures and limits (ECSS) |
|-----|---|------------------|---|--------------------------|---------------------------|-----------------------------------|
| 1   | Power Bus conducted Interference , load induced, audio frequency                    | 30Hz - 150kHz    | A   | -                        | DM, Tailored              | Tailored                          |
| 2   | Power Bus conducted Interference , load induced, audio frequency                    | 150kHz - 20MHz   | A   | -                        | CE03, MIL462 up to 200MHz | Tailored                          |
| 3   | RF common mode conducted emissions, power and signal cables                         | 150kHz - 20MHz   | A   | A                        | -                         | Tailored                          |
| 4   | Conducted Emission, Antenna Terminal  | 10kHz - 40GHz    | L   | L                        | Tailored                  | -                                 |
| 5   | Conducted Emission, Differential Mode, Time Domain, Load Induced Voltage Transients | Transients       | A   | -                        | -                         | -                                 |
| 6   | Audio Frequency Conducted Susceptibility, Power leads                               | 30Hz - 150kHz    | A   | A                        | -                         | Tailored                          |
| 7   | Audio Frequency Conducted Susceptibility, Antenna Port, Intermodulation             | 15kHz - 10GHz    | S   | S                        | Tailored                  | -                                 |
| 8   | Conducted Susceptibility, Antenna Port, Rejection of undesired Signals              | 30Hz - 20GHz     | S   | S                        | Tailored                  | -                                 |
| 9   | Conducted Susceptibility, Antenna Port, Cross-Modulation                            | 30Hz - 20GHz     | S   | S                        | Tailored                  | -                                 |
| 10  | Conducted Susceptibility, Bulk Current Injection, Swept Frequency                   | 10kHz - 200MHz   | A   | A                        | Tailored                  | Limit and Test method provided    |
| 11  | Conducted Susceptibility, Bulk Current Injection, Excitation                        | Impulses         | S   | A                        | -                         | -                                 |
| 12  | Conducted Susceptibility, Damped Sinusoidal Transients                              | 10kHz - 100MHz   | A   | A                        | Applied case by case      | -                                 |
| 13  | Conducted Susceptibility, Ground Plane Injection Spike                              | Spikes           | A   | -                        | -                         | Tailored                          |
| 14  | Conducted Susceptibility, Ground Plane Injection, Audio Frequency                   | 30Hz - 150kHz    | A   | -                        | -                         | -                                 |
| 15  | Conducted Susceptibility, Ground Plane Injection, Radio Frequency                   | 150kHz - 100MHz  | A   | -                        | -                         | -                                 |
| 16  | Susceptibility to switching Transients, Power leads, Time Domain                    | Transients       | A   | -                        | -                         | -                                 |
| 17  | Conducted Emissions, Common Mode Power and Signal Lines                             | 10kHz -200MHz    | -   | -                        | NEW                       | -                                 |
| 18  | RE, low frequency Magnetic field  | Specific - 50kHz | -   | -                        | -                         | Analysis needed                   |
| 19  | RE, low frequency Electric field  | Specific - 30MHz | -   | -                        | -                         | Analysis needed                   |

# SPACE SYSTEMS – EMC TEST DIFFERENCES 2



| Comparison Table |  |               |   |                          |  |  |
|------------------|--|---------------|---|--------------------------|--|--|
| S/N              | Description  | Frequency     | Launch Vehicle, Space Vehicle systems and subsystems (AIAA) | Space systems (MIL 461G) | EMI Requirement (GSFC)                   | Test procedures and limits (ECSS)      |
| 20               | Radiated Emission, Magnetic Field  | 30Hz - 100kHz | S   | -                        | Applicable, Alt. RE04, MIL462 available. | -                                      |
| 21               | Radiated Emission, Electric Field  | 20MHz - 18GHz | A   | A                        | Applicable, Alt. Test method available   | Limit provided. Setup: RE102           |
| 22               | Radiated Emission, antenna spurious and harmonic output                        | 10kHz - 40GHz | L   | L                        | -  | -                                      |
| 23               | Radiated Susceptibility, Magnetic Field  | 30Hz -100kHz  | S   | -                        | Tailored                                 | Immunity level provided. Setup: RS101  |
| 24               | Radiated Susceptibility, Electric Field  | 2MHz-40GHz    | A   | A                        | Tailored                                 | Immunity level provided. Setup: RS103  |
| 25               | Conducted Susceptibility, Lightning Induced Transients, cables and power leads | Transients    | L   | L                        | Applied case by case                     | -                                      |
| 26               | Electrostatic Discharge Susceptibility, Personnel Borne                        | Transients    | L   | -                        | Applied case by case                     | Legacy and Alternate method specified. |
| 27               | Conducted Emissions, Turn-on Transient   | Transients    | -   | -                        | NEW                                      | -                                      |
| 28               | Conducted Susceptibility, Transients, Power Leads                              | Transients    | -   | -                        | CS06, MIL462                             | -                                      |
| 29               | CE on power leads, in-rush currents  | Transients    | -   | -                        | -  | Limit and Test method provided         |
| 30               | DC Magnetic field emission   | Transients    | -   | -                        | -  | Limit and Test method provided         |
| 31               | CS, power leads, short spike transients  | Transients    | -   | -                        | -  | Limit and Test method provided         |

# AIAA APPLICABLE TO SPACE SYSTEMS (EMI)



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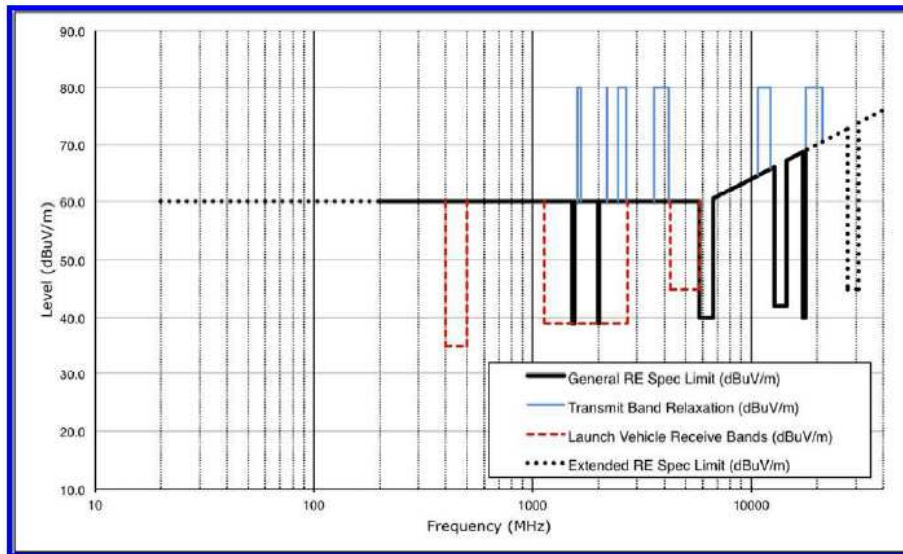


Figure 21 – Spacecraft and Launch Vehicle Radiated Emissions Limit

| Frequency Range (Hz) | 6dB Resolution BW (Hz) | AIAA TABLE II. Bandwidth and Measurement time |   |   |
|----------------------|------------------------|---|---|---|
|                      |                        | Stepped Tuned Receiver (S)                    | Min. Dwell time FFT Receiver (S/measurement BW) | Min. Measurement Time Analog Tuned Measurement Receiver |
| 30-1k                | 10                     | 0.15  | 1   | 0.015sec/Hz   |
| 1k-10k               | 100                    | 0.015   | 1   | 0.15sec/kHz   |
| 10k-150k             | 1k                     | 0.015   | 1   | 0.015sec/kHz  |
| 150k-10M             | 10k                    | 0.015   | 1   | 1.5sec/MHz  |
| 10M-30M              | 10k                    | 0.015   | 0.15  | 1.5sec/MHz  |
| 30M-1G               | 100k                   | 0.015   | 0.15  | 0.15sec/MHz   |
| Above 1G             | 1M                     | 0.015   | 0.015   | 15sec/GHz   |

- A.4 Limit lines are in RMS values. Peak detector returns the rms equivalent of the peak of the modulation envelope. - pg 54  
 - Bandwidth and measurement time is with reference to MIL461G section 4.3.10.3.1  
 - Set-up and testing in accordance to MIL-STD-461G

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# GSFC APPLICABLE TO SPACE SYSTEMS (EMI)



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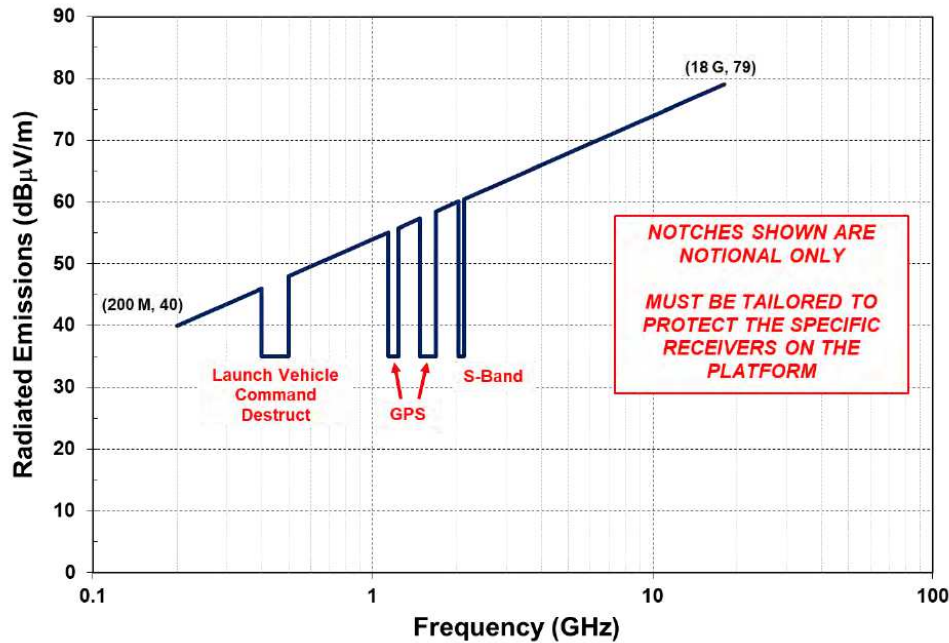


Figure 2.5-27 Radiated Emissions Electric Field Limit with Suggested Notches

| GSFC TABLE II. Bandwidth and Measurement time |             |                 |                                    |
|---|-------------|-----------------|------------------------------------|
| Frequency Range (Hz)                          | 6dB BW (Hz) | Min. Dwell time | Min. Measurement Time Analog-Tuned |
| 30-1k   | 10          | 0.15            | 0.015sec/Hz                        |
| 1k-10k  | 100         | 0.015           | 0.15sec/kHz                        |
| 10k-150k                                      | 1k          | 0.015           | 0.015sec/kHz                       |
| 150k-30M                                      | 10k         | 0.015           | 1.5sec/MHz                         |
| 30M-1G  | 100k        | 0.015           | 0.15sec/MHz                        |
| Above 1G                                      | 1M          | 0.015           | 15sec/GHz                          |

- Bandwidth and measurement time is with reference to MIL461E section 4.3.10.3.1-Table 2  
 - Peak detections, 200MHz – 18GHz  
 - Set-up and testing in accordance to MIL-STD-461G

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# ECSS APPLICABLE TO SPACE SYSTEMS (EMI)



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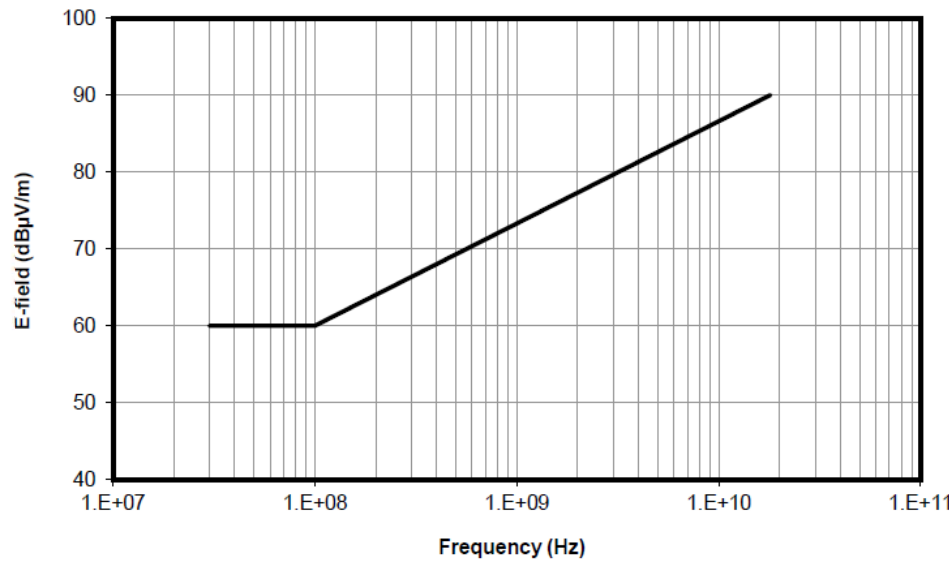


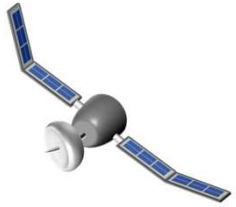
Figure A-3: Radiated electric field limit

| ECSS TABLE 5-2. Bandwidth and Measurement time |             |                              |                                    |
|--|-------------|------------------------------|------------------------------------|
| Frequency Range (Hz)                           | 6dB BW (Hz) | Min. Dwell time Receiver (S) | Min. Measurement Time Analog-Tuned |
| 30-1k  | 10          | 0.15                         | 0.015sec/Hz                        |
| 1k-10k   | 100         | 0.015                        | 0.15sec/kHz                        |
| 10k-150k                                       | 1k          | 0.015                        | 0.015sec/kHz                       |
| 150k-30M                                       | 10k         | 0.015                        | 1.5sec/MHz                         |
| 30M-1G   | 100k        | 0.015                        | 0.15sec/MHz                        |
| Above 1G                                       | 1M          | 0.015                        | 15sec/GHz                          |

- Bandwidth and measurement time is with reference to MIL461E section 4.3.10.3.1-Table 2  
 - Video filtering shall not be used to bandwidth limit the receiver response. If is available on the measurement receiver, it shall be set to its greatest value. (Such requirement are not stated in AIAA and GSFC).  
 - Peak detections, 200MHz – 18GHz  
 - Set-up and testing in accordance to MIL-STD-461G

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# SPACE SYSTEMS – EMI TEST DIFFERENCES



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| Space systems – EMI Test differences |  |   |   |
|--------------------------------------|--|---|---|
| S/N/AIAA                             | AIAA<br>SHAPING THE FUTURE OF AEROSPACE  | GSFC<br>NASA  | ECSS  |
| 1                                    | EMI Safety Margin <b>provided according to Category and critical systems</b>                             | Guidelines for defining system level EMC testing are provided in <b>MIL-STD-464C</b> , Electromagnetic Environmental Effects Requirements for Systems. No EMISM provided. | EMISM are not provided but the <b>means of validating the EMISM are provided</b>  |
| 2                                    | Reference for bandwidth and measurement time indicated <b>requirement for FFT</b>                        | <b>Acknowledged FFT saves time</b> and suitable for detecting transient signal. But no guideline provided for the use of FFT.   | <b>FFT testing are not mentioned.</b>   |
| 3                                    | EMI limit lines provided for different category of systems. <b>Guidelines provided for Notch filters</b> | Generic EMI limit lines provided for different category of systems. <b>Guidelines provided for Notch filters</b>  | Generic EMI limit lines provided for different category of systems. <b>No Guideline provided for harmonics testing.</b> |

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# AIAA APPLICABLE TO SPACE SYSTEMS (EMS)



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| AIAA TABLE 2. Ground operations through launch SV/LV separation |                              |  |
|---|------------------------------|--|
| Frequency Range (Hz)  | Environment Level V/m (Peak) | Modulation   |
| 2M - 18G  | 20                           | Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle   |
| 18G - 40G<br>(Required only if specified in procurement Spec)   | 20                           | CW (no modulation) Pulse Modulated 1 kHz rate with a 1 μs pulse width              |
| 2G - 2.5G   | 100                          | CW (no modulation)   |
| 5.4G - 5.9G   | 100                          | Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 1 μs pulse width |

- NOTE 1 Pre-launch includes integration and test (I&T) and transportation to the launch facility.  
 - NOTE 2 The pre-launch RF environment requires coordination with the range, (e.g., Program Requirements Document (PRD), Range Requirements Document (RRD), etc.); levels at some ranges may be higher than shown here.

| AIAA TABLE 3. On-Orbit  |                              |  |
|---|------------------------------|--|
| Frequency Range (Hz)  | Environment Level V/m (Peak) | Modulation   |
| 2M - 18G  | 20                           | Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle   |
| 18G - 40G<br>(Required only if specified in procurement Spec) | 20                           | CW (no modulation) Pulse Modulated 1 kHz rate with a 1 μs pulse width              |
| 2G - 2.5G   | 50                           | CW (no modulation)   |
| 5.4G - 5.9G   | 50                           | Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 1 μs pulse width |

| AIAA (MIL-STD-461G) TABLE III. Susceptibility scanning |  |                                  |
|--|--|----------------------------------|
| Frequency Range (Hz)                                   | Analog Scans Maximum Scan Rates (fo/sec) | Stepped Scans Max Step Size (fo) |
| 30 - 1M  | 0.0333                                   | 0.05                             |
| 1M - 30M   | 0.00667                                  | 0.01                             |
| 30M - 1G   | 0.00333                                  | 0.005                            |
| 1G-40G   | 0.00167                                  | 0.0025                           |

- Susceptibility scanning is with reference to MIL461G 4.3.10.4.2. Except Dwell time is to extend to 3s of the EUT response time, whichever that is greater.  
 - Thresholds testing needs to be done and recorded if EUT failed acc. MIL461G .  
 - Test support equipment used to show threshold of susceptibility should automate output of test equipment to trip when threshold is exceeded, rather than relying on visual monitoring of the unit.  
 - A suitable method of monitoring each performance parameter necessary to qualify the equipment shall be employed to detect the threshold(s) of susceptibility if or when exceeded. This may be provided by a built-in-test function or other indication to monitor the EUT performance, preferably in real-time.  
 - Prior to the start of each susceptibility test, the pass/fail criteria shall be predetermined, and the course of action to follow, should susceptibility occur, shall also be predetermined.

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# GSFC APPLICABLE TO SPACE SYSTEMS (EMS)



| GSFC Radiated Susceptibility, Electric Field   |                              |  |   |
|--|------------------------------|--|---|
| Frequency Range (Hz)   | Environment Level V/m (Peak) | Modulation   | Remarks   |
| 2M - 18G   | 20                           | Pulse Modulated<br>(on/off ratio of 40 dB minimum)<br>1 kHz rate with a 50% duty cycle | Equipment that will be <b>on</b> during launch.                             |
| 2M - 18G   | 2                            | Pulse Modulated<br>(on/off ratio of 40 dB minimum)<br>1 kHz rate with a 50% duty cycle | Equipment that will be <b>off</b> during launch. Min. on orbit environment. |
| <p>- "Common Mode Conducted Emission (CMCE)" will be addressed by CS114 test method.</p> <p>- Spot size is referred to the antenna beamwidth as described in MIL461G, RS103.<br/>Reference to MIL 461F, Antenna distance can be greater than 1m to allow bigger spot size.</p> <p>- Equipment that will not be powered on during launch, but that may be powered on during any portion of the test campaign at the launch site, should be tested to the launch site levels in addition to the on-orbit levels.</p> <p>- Equipment that will not be powered on during launch is only required to survive the launch RS levels without damage. "Survive-without-damage" requirements. An approach for such an analysis is outlined in section 2.5.3.3.8.</p> |                              |  |   |

| GSFC Table 2.5-1. Susceptibility Scanning (Replacement for MIL-STD-461G Table III)  |  |                                  |
|---|--|----------------------------------|
| Frequency Range (Hz)  | Analog Scans Maximum Scan Rates (fo/sec) | Stepped Scans Max Step Size (fo) |
| 30 - 1M   | 0.0333                                   | 0.05                             |
| 1M - 30M  | 0.00667                                  | 0.01                             |
| 30M - 1G  | 0.00333                                  | 0.005                            |
| 1G-18G  | 0.00167                                  | 0.01                             |
| <p>- Scanning from 18 to 40 GHz is only required if specified in the procurement specification, and it should be specified only if there are specific transmitters operating in that frequency range that pose a concern</p> <p>- 1 GHz to 18 GHz frequency range, the maximum scan rate and maximum step size are increased by a factor of 4 over the values in MIL-STD-461G Table III.</p> <p>- Thresholds testing needs to be done and recorded if EUT failed acc. MIL461G .</p> <p>- Test support equipment used to show threshold of susceptibility should automate output of test equipment to trip when threshold is exceeded, rather than relying on visual monitoring of the unit.</p> <p>- Prior to the start of each susceptibility test, the pass/fail criteria shall be predetermined, and the course of action to follow, should susceptibility occur, shall also be predetermined.</p> |  |                                  |

# ECSS APPLICABLE TO SPACE SYSTEMS (EMS)



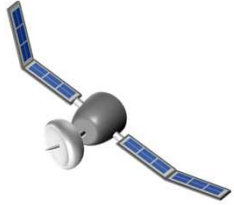
| ECSS Table 2.5-1. Susceptibility Scanning (Replacement for MIL-STD-461G Table III) |            |  |  |
|--|------------|--|--|
| Frequency Range (Hz)   | V/m (Peak) | Modulation   | Remarks  |
| 30M-18G  | 10         | Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle | Equipment in the vicinity of transmission beams, outside of the main frame   |
| 30M-18G  | 1          | Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle | Equipment far from main lobes and secondary lobes, outside of the main frame |
| 30M-18G  | 1          | Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle | Equipment inside the main frame  |

- Thresholds testing needs to be done when susceptibility had been noted. Acc. to steps in ECSS and recorded if EUT failed acc. MIL461G .  
 - An electric field of more than 10 V/m is applied if RF analysis demonstrates that the expected electric field seen in flight by the equipment is larger.  
 Reports: Freq. res. 1%, Amplitude res. 1dB. system correction factors (attenuators, transducers , cable loss and etc...)  
 Beamwidth is similar to MIL 461G except for below 200MHz.  
 - Additional requirements can apply beyond 18 GHz if SHF or EHF payloads are present.




| ECSS Table 5-3. Susceptibility Scanning |                                  |
|---|----------------------------------|
| Frequency Range (Hz)                    | Stepped Scans Max Step Size (fo) |
| 30-100k                                 | 0.05                             |
| 100k-3M                                 | 0.05                             |
| 3M-30M                                  | 0.02                             |
| 30M-50M                                 | 0.02                             |
| 50M-200M                                | 0.01                             |
| 200M-1G                                 | 0.01                             |
| 1G-18G                                  | 0.01                             |

- Stepped scans shall dwell, exclusive of test equipment settling time, at each tuned frequency for the greater of one second or the EUT response time, within the limit of ten seconds.  
 - Each item of equipment and subsystem shall have successfully passed functional acceptance test procedures as installed on the platform, prior to system level EMC test.

# SPACE SYSTEMS – EMS TEST DIFFERENCES



Rohde & Schwarz

| Space systems – EMS Test differences |   |  |   |
|--------------------------------------|---|--|---|
| S/N                                  | <br><b>AIAA</b><br>SHAPING THE FUTURE OF AEROSPACE | <br><b>NASA</b>                               | <br><b>ECSS</b>      |
| 1                                    | EMS immunity requirement provided according to Category and critical systems.   | EMS immunity requirement provided according to when the system will be on/off.   | EMS immunity requirement provided based on proximity to transmission beams and location of the systems. |
| 2                                    | Susceptibility scanning based on MIL461G.   | Susceptibility scanning based on MIL461G with deviation from 1GHz - 18GHz.   | Susceptibility scanning with different definition.  |
| 3                                    | Immunity Threshold testing according to MIL461G.  | Immunity Threshold testing according to MIL461G with additional guideline. Automation to monitoring of susceptibility suggested. | Immunity Threshold testing according to MIL461G with additional guideline.                              |

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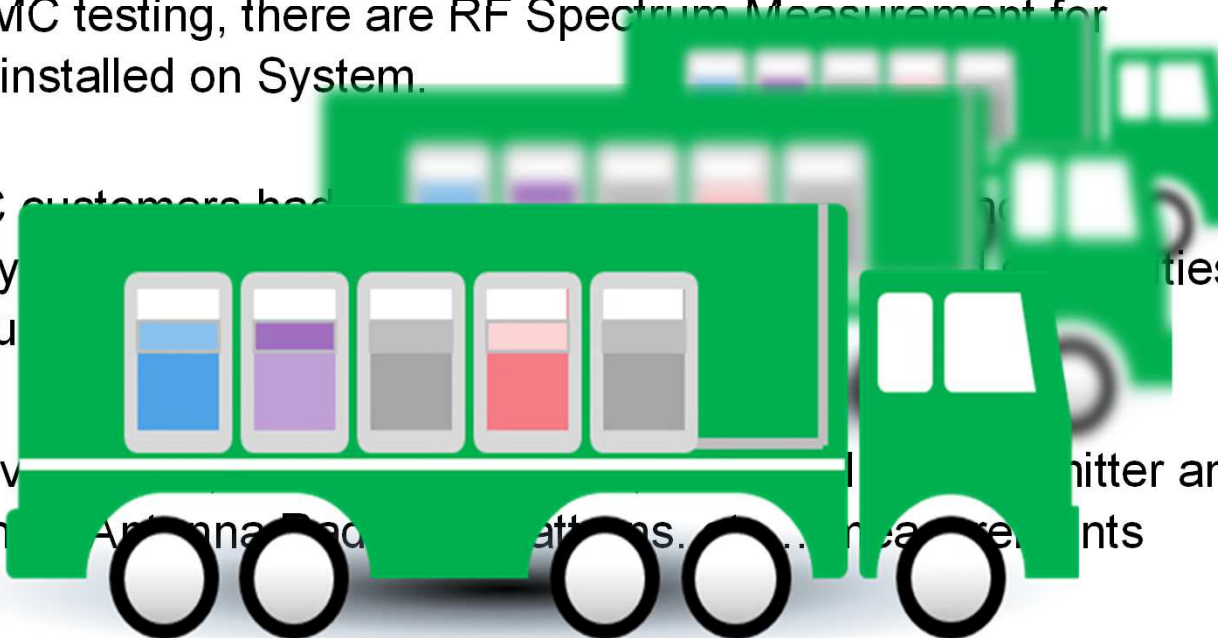
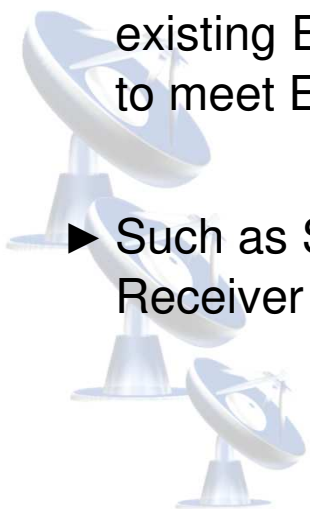
# ELECTROMAGNETIC ENVIRONMENT EFFECTS IN THE A&D DOMAIN EMC TESTS ARE SUMMARIZED AS E3



▶ Beside Standard EMC testing, there are RF Spectrum Measurement for Transmitters which installed on System.

▶ Some existing EMC customers had existing EMC test systems to meet E3 test requirements

▶ Such as System Level Receiver Performance, Antenna Radiation Patterns, etc.





# THE IMPORTANCE OF SYSTEM LEVEL EME EFFECTS TEST

What are the differences ?

- Operate according to requirements (Fix environment)
- Frequency domain
- Research and design work
- According to test methods

## System Level

- Operational environmental conditions (no definition!)
- Analysis of EM interference
- Time and frequency domain
- In launch and space condition with critical limits varies

## Standard EMC Test

# E3-MARGIN

1. Establish the external threat environment against which the system is required to demonstrate compliance of immunity.
2. Identify the system electrical and electronic equipment performing functions required for operation during application of the external threat.
3. Establish the internal environment caused by external electromagnetic effects for each installed equipment.
4. Design the system and equipment protection.
5. Verify the protection adequacy, typically require an overall margin of 6 dB (16.5dB for EIDs).

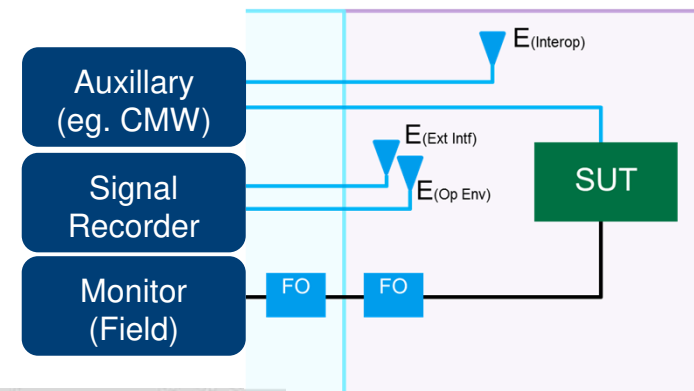
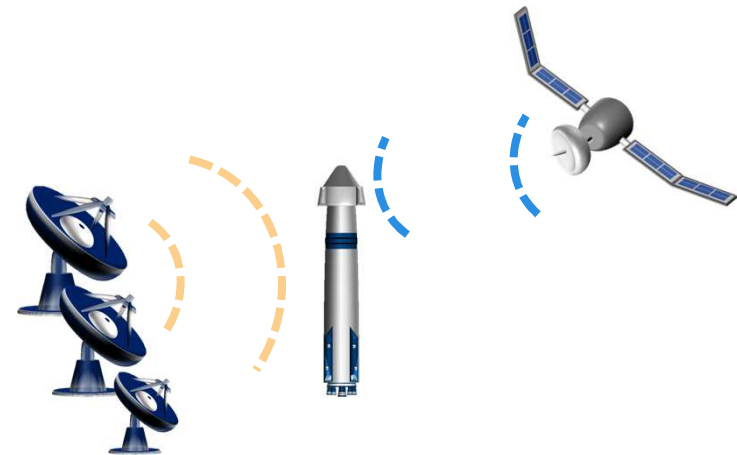
# E3-MARGIN EVALUATION TEST METHODOLOGY

## Field to Lab Concept

1. Place Platform in Operation Scenario
2. Measurement on the parameters (V/m, V, dBuA etc)
3. Record Signal Characteristic strength, Modulation etc
4. Post Processing in Lab (Optional)
5. Replay in Lab directly to the EUT (If lab has relevant Instrument/Amplifier)

## Advantages

- a. Suitable for big Platform (Ship, Sub or Aircraft)
- b. Reduce cost of ownership

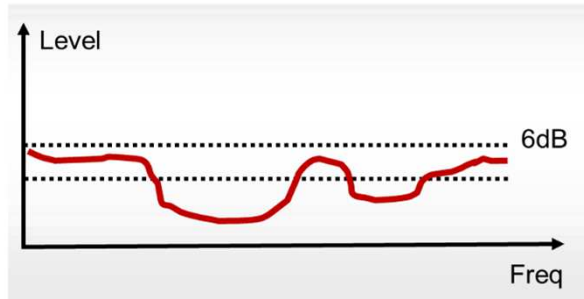
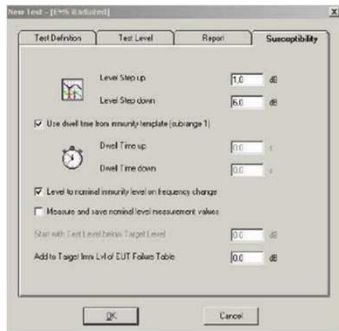


$$E(\text{dB}) = E_{(\text{Interop})}(\text{dB}) + E_{(\text{Op Env})}(\text{dB}) + E_{(\text{Ext Intf})}(\text{dB})$$

# E3-MARGIN EVALUATION

## Evaluation Techniques

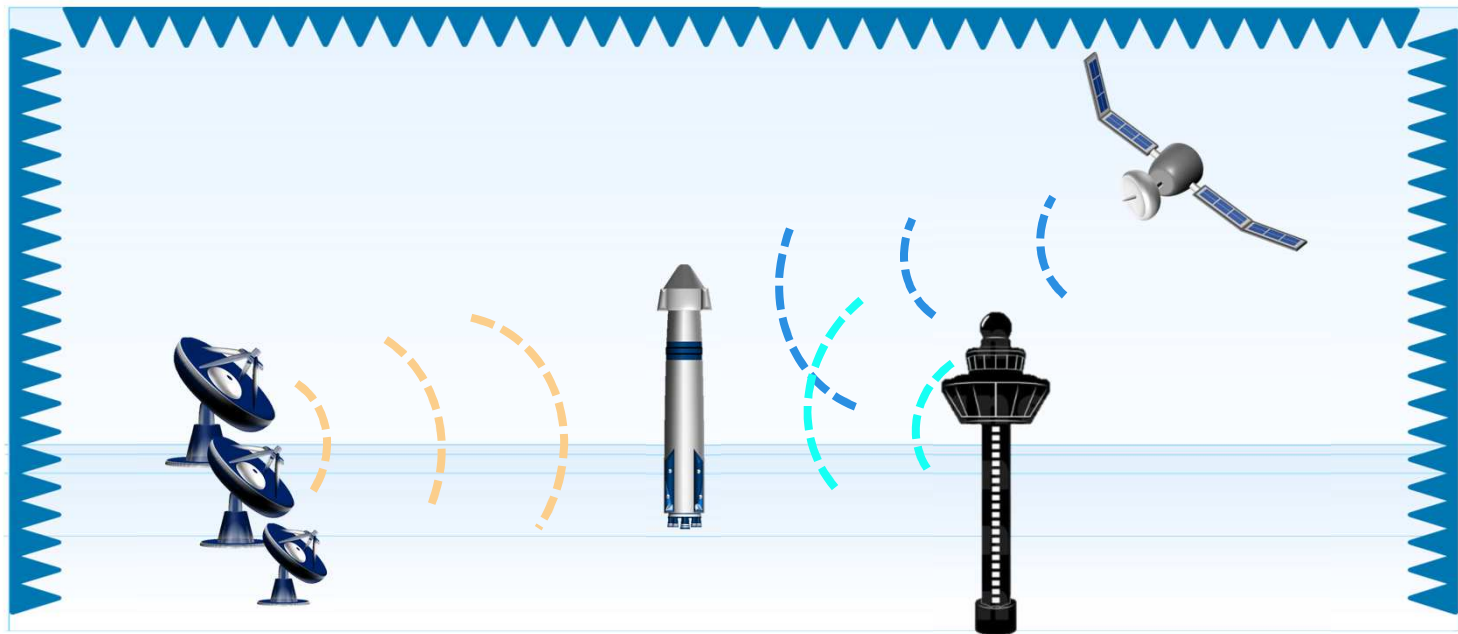
1. SUT **Max allowable limit** is known or;
2. SUT **Immunity level** is known



| Test Name             | Range       | AntPos | AntDis | AntPol | Sensor    |
|-----------------------|-------------|--------|--------|--------|-----------|
| Product One - Eut One | 200MHz-1GHz | 45Deg  | 1      | H      | Location1 |
| Product One - Eut One | 200MHz-1GHz | 45Deg  | 1      | H      | Location2 |
| Product One - Eut One | 200MHz-1GHz | 45Deg  | 1      | V      | Location1 |
| Product One - Eut One | 200MHz-1GHz | 45Deg  | 1      | V      | Location2 |
| Product One - Eut One | 1GHz-3GHz   | 45Deg  | 1      | V      | Location1 |
| Product One - Eut One | 1GHz-3GHz   | 45Deg  | 1      | V      | Location2 |
| Product One - Eut One | 1GHz-3GHz   | 45Deg  | 1      | H      | Location1 |
| Product One - Eut One | 1GHz-3GHz   | 45Deg  | 1      | H      | Location2 |

# EME EFFECTS TESTING IN THE CHAMBER

Autonomous, EME Complexity, Coexistence and Connectivity are in futuristic battlefield



Demystifying EMC 2023 virtual conference

# SATELLITE EMC TESTING

q&a

Thank you for listening.

For any questions please contact us via chat.

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Make ideas real

