# A Satellite Operator's Perspective and Requirements

## SKYNET 5 – UK Military Communications
## SMA 170

Ewan Haggarty, Spacecraft Management Authority
11 May 2015



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# SKYNET Constellation

Four SKYNET 5 Geostationary satellites using the Eurostar 3000 bus.

- Design Life 12 years ( plus 3 years with unconstrained inclination )
- SKYNET 5A launched 11 March 2007, so now mid-life

Four SKYNET 4 class Geosynchronous satellites using the ECS bus

- Design Life 7 years ( launched into inclined orbit < 3.5° )
- Oldest is SKYNET 4C, launched on 30 August 1990
- All SKYNET 4s have highly inclined orbits

This mixture of old and new technology gives us an insight into Space Weather issues.





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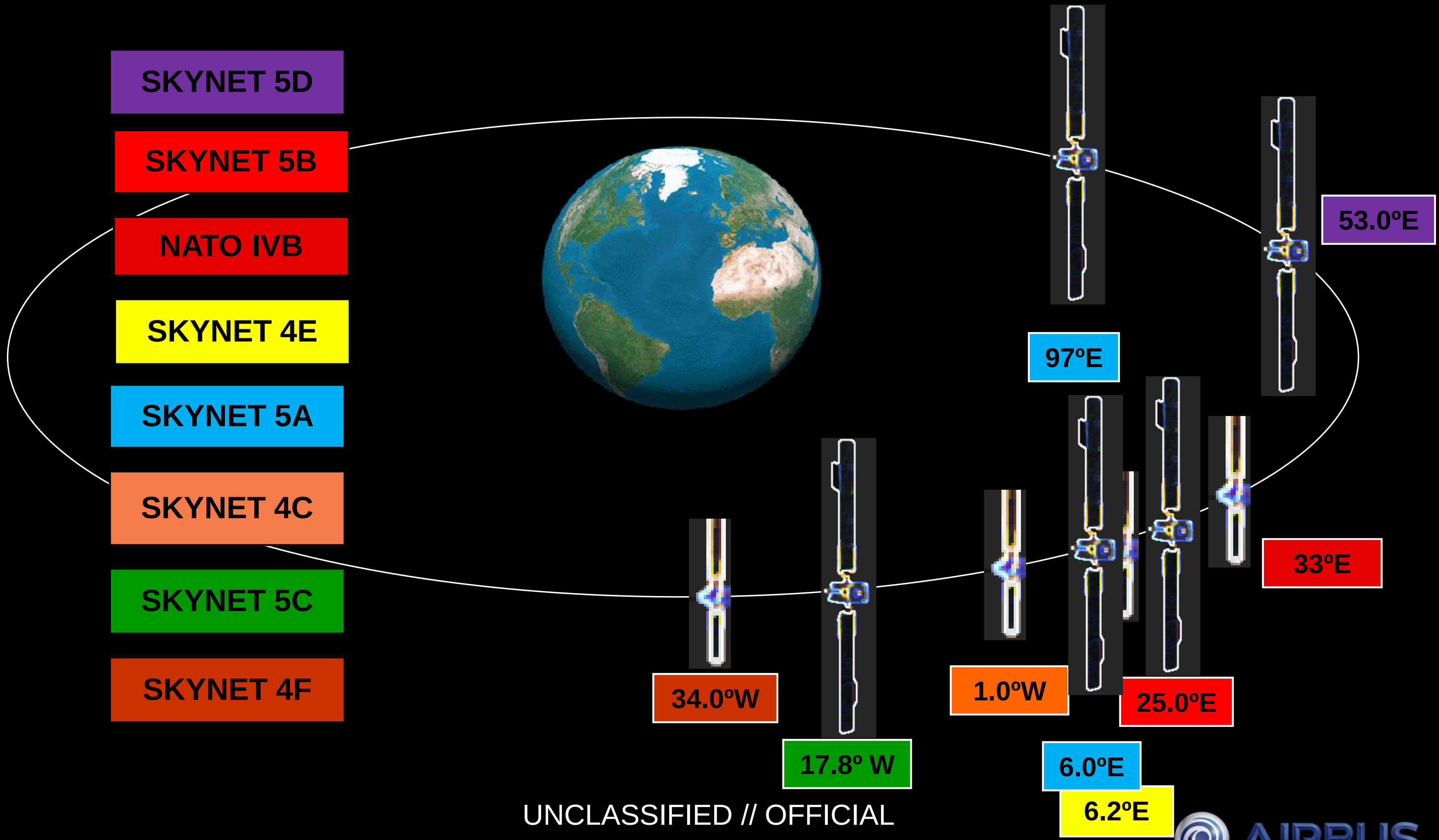
# SKYNET Fleet (11 May 15)





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# Environmental Monitoring Requirements

In providing services through the SKYNET constellation, we require knowledge of the space environment:

1. Certain Spacecraft ‘Anomalies’ are associated with changes in charged particle fluence. Evolution of these Anomalies is tracked, with environmental exposure a principal variable.

2. When new Anomalies appear, the Space Environment is considered.

3. We will issue notification to our customers if certain charged particle flux levels are exceeded where we have determined there is an increase in risk of a service-interrupting anomaly.

We monitor the function of spacecraft subsystems in the space environment, assessing their degradation rate against manufacturer forecast and general fleet behaviour.

# Procedural Approach Requirements

We have detailed Procedures allowing SKYNET Spacecraft Operations to mitigate many types of risk. To do this we have:

1. Procedurally complete 'Responses' to well defined 'Triggers' which may be implemented with minimal interpretation.

2. 'Responses' and 'Triggers' are balanced, so we neither:
   - 'Wish we had gone up/ down a level when we had the chance' nor
   - 'Wish we hadn't done that'.

3. Procedures are designed with reversibility with minimal impact on space asset capability, diversity and lifetime following any 'triggered response'.

We are developing Procedures to mitigate Extreme Space Weather threats in the same manner.





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# Estimating the Risk of an Extreme Space Weather Event

There is much debate on the level of the Extreme Space Weather threat.

The possibility of Extreme Space Weather to interrupt services is understood and accepted at a fairly high Governmental and cerebral/ academic levels, but not well embraced by in-situ engineering support and customers, who legitimately ask:

- What are the chances of that, then?
- What could happen if it did?
- You do realise making changes cost money ..?

Business Accountants wish to see Assured Return on Investment.

Outlay on something 'not believed in' as it has not been lived through is notoriously difficult to secure.

# Estimating the Risk of an Extreme Space Weather Event

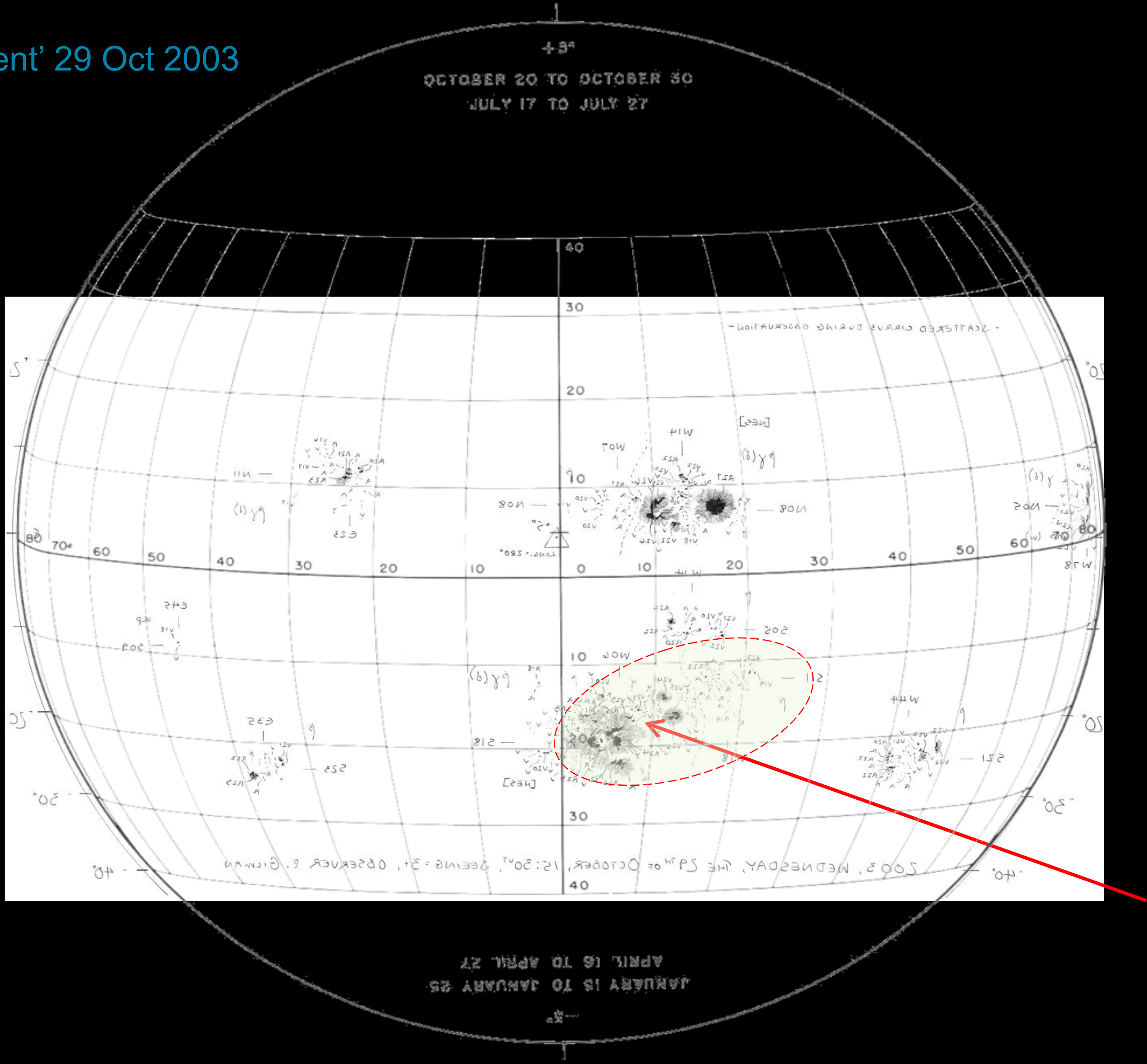
Taking one type of Extreme Space Weather event in isolation – A large Coronal Mass Ejection resulting on a 'direct hit' on the Earth – only the 'Halloween Event' of 29 Oct 2003 has been notable in SKYNET history.

- Probability of an 'large event' based on location on Sun = 2/27 ~ 7%.
- Probability of any single 'large event' missing based on solar location ~ 93%.
- If a 'large event' is defined as being associated with a > M1 flare, incidence since 1976 ( 2½ 11-year Sunspot Cycles ) suggests there are ~ 140 per Sunspot Cycle.
- Magnetic Polarity of the CME means the effect is significantly higher if it is South oriented, so we might assume the number of potentially 'large effective events' per Sunspot Cycle ~ 70.

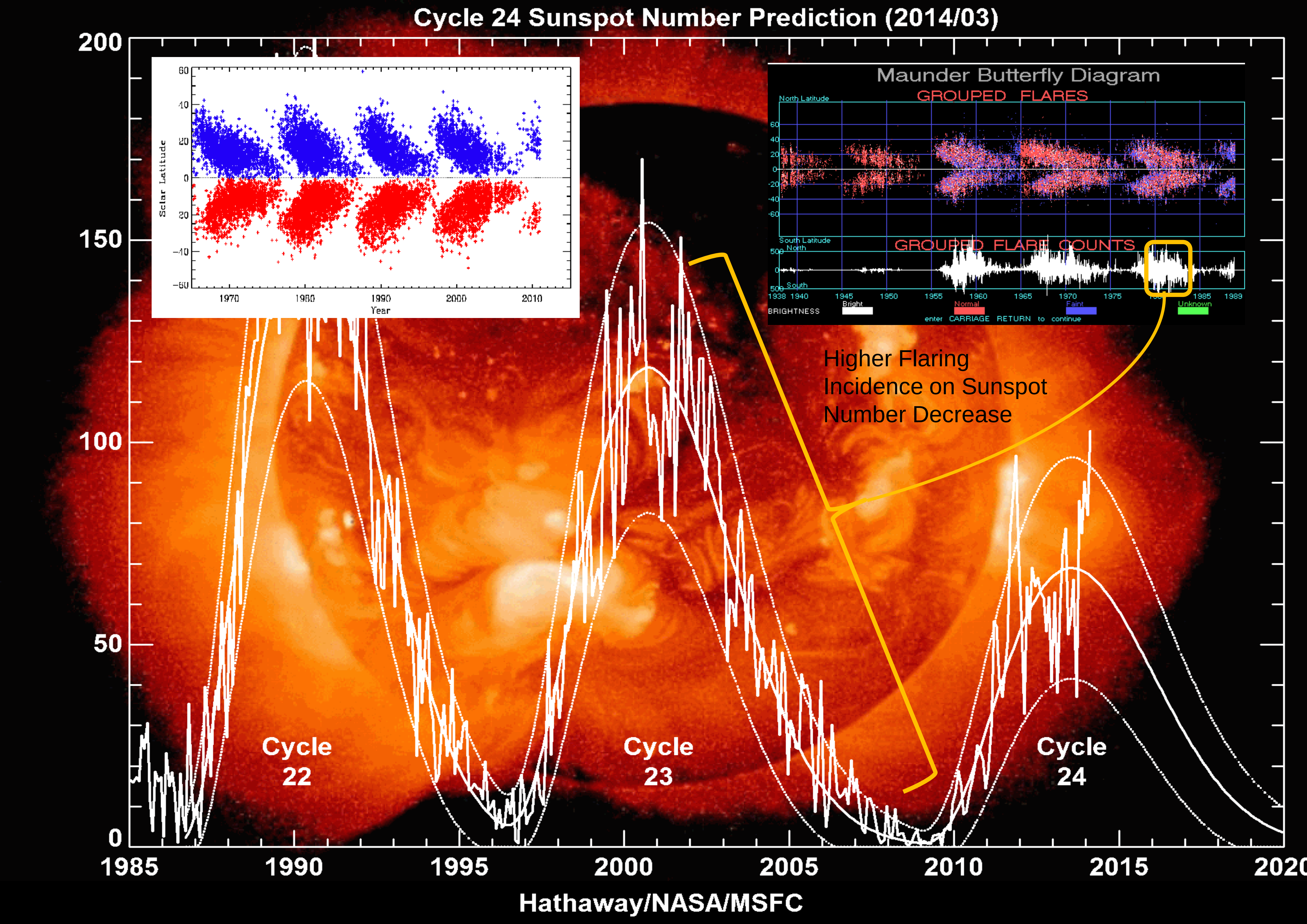
Chance of *missing* a 'large effective event' during a Sunspot Cycle = $0.93^{70}$ ~ 0.5%.

## The ‘Halloween Event’ 29 Oct 2003

11 SKYNET 4 Anomalous events in a 48-hour period.

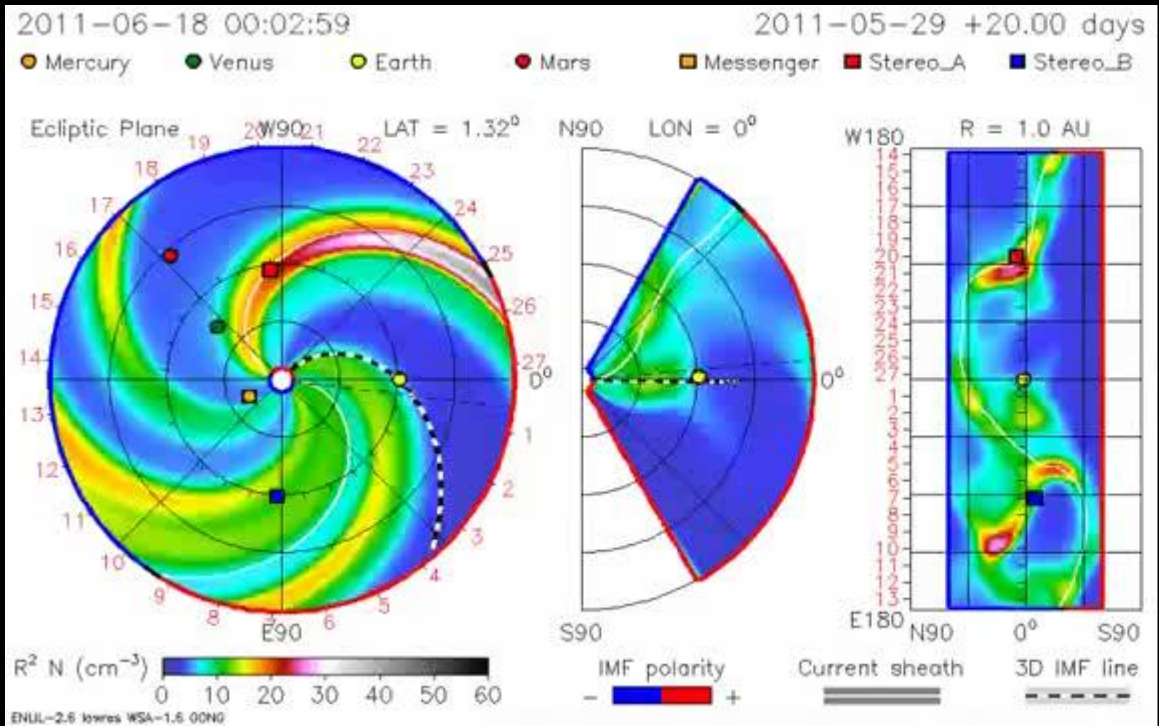


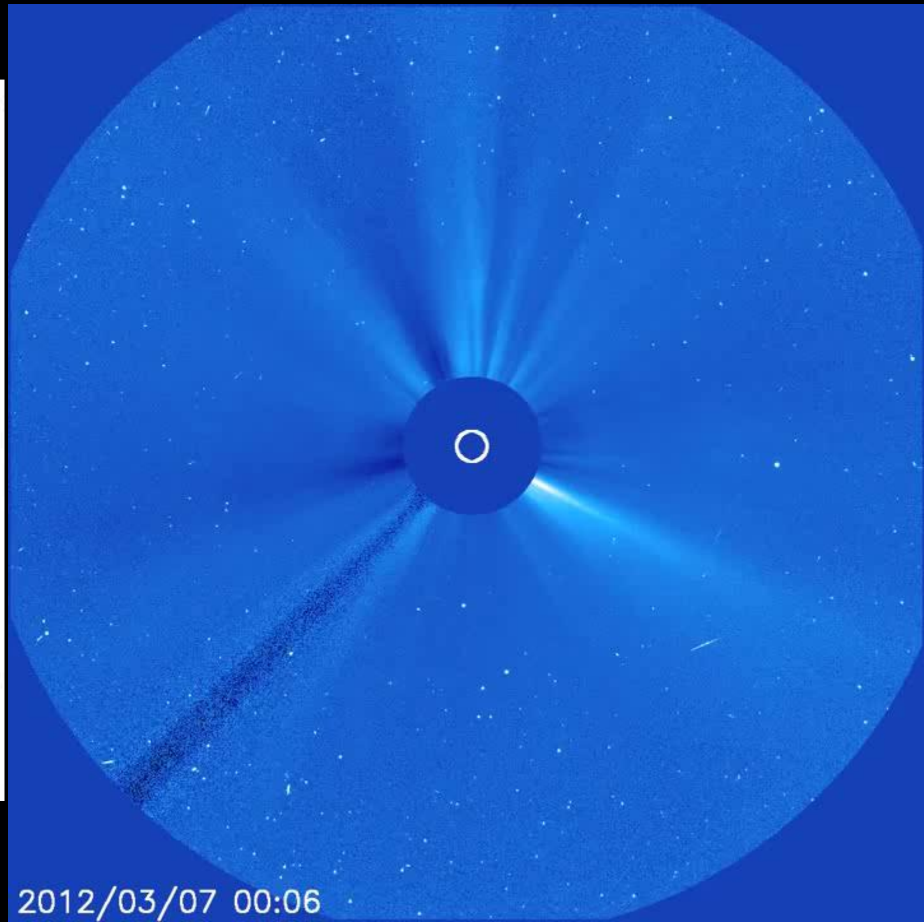

An X17 Flare at S16E08, 1110z.



Cycle 24 Sunspot Number Prediction (2014/03)
200
150
100
50
0
1985
1990
1995
2000
2005
2010
2015
2020
Cycle 22
Cycle 23
Cycle 24
Hathaway/NASA/MSFC
Solar Latitude
Year
Maunder Butterfly Diagram
GROUPED FLARES
North Latitude
South Latitude
GROUPED FLARE COUNTS
BRIGHTNESS
Bright
Normal
Faint
Unknown
enter CARRIAGE RETURN to continue
Higher Flaring
Incidence on Sunspot
Number Decrease

# Coronal Mass Ejection Modelling and Monitoring





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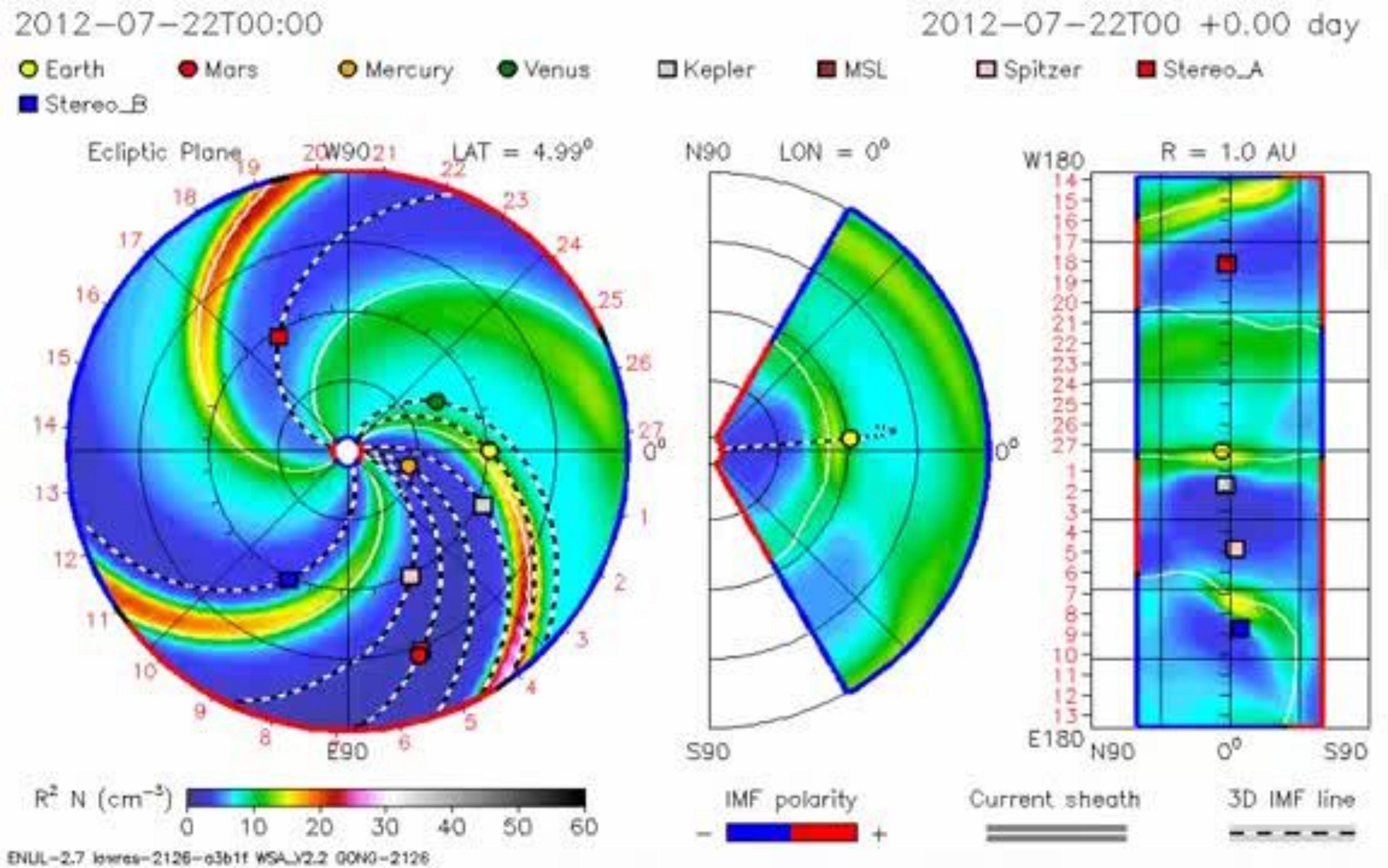
# The ‘Olympic’ CME





# MOSWOC Forecast Capability Development and Support

The MOSWOC is at the forefront of Space Weather Prediction and 'own' the UK Space Weather risk.

We have been supported by the MOSWOC and through our Principal Customer the MOD, QinetiQ in running Tabletop Exercises to develop our outline Operational Response.

MOSWOC continue to be proactive in developing their Forecast Output.

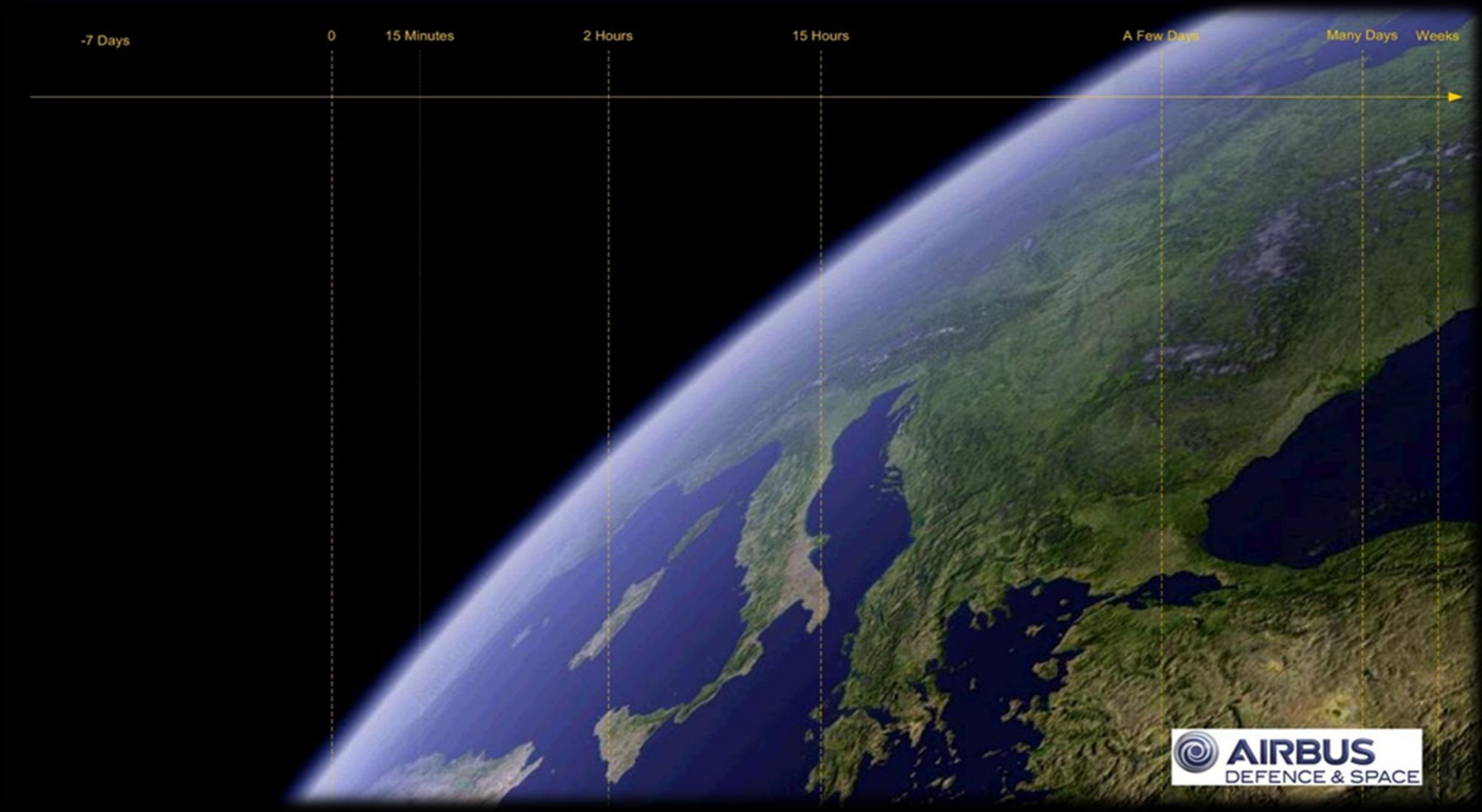
We have had a very successful Space Weather Trainer – Space Operations Trainer 'cultural exchange'.

The aim is to have documented and rehearsed procedures in place Q4 2015.

# Monitoring Approach – MOSWOC Forecasts and Advice

The MOSWOC provides us with a twice-daily forecast and Solar conditions analysis. Working with them, we are jointly defining the release of Advice to us real-time, when needed:

- **NOTIFICATION** when a Solar Feature has potential to cause Extreme Space Weather.
- **WARNING** when a Solar Feature is expected to be a source of Extreme Space Weather.
- **ALERT** when a Solar Feature has produced Extreme Space Weather which demands mitigative action.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AIRBUS
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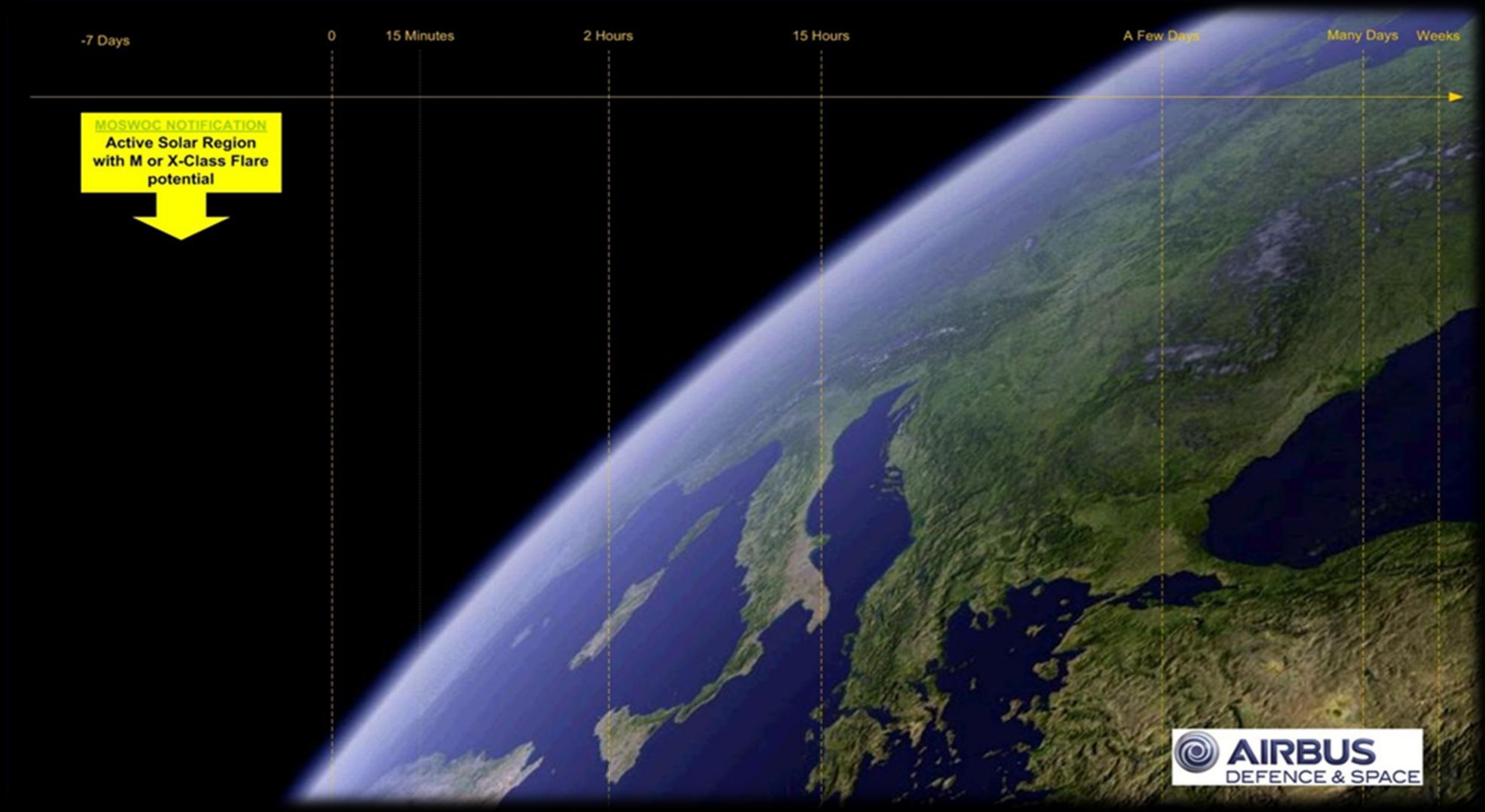
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Active Solar Region with M or X-Class Flare potential
AIRBUS
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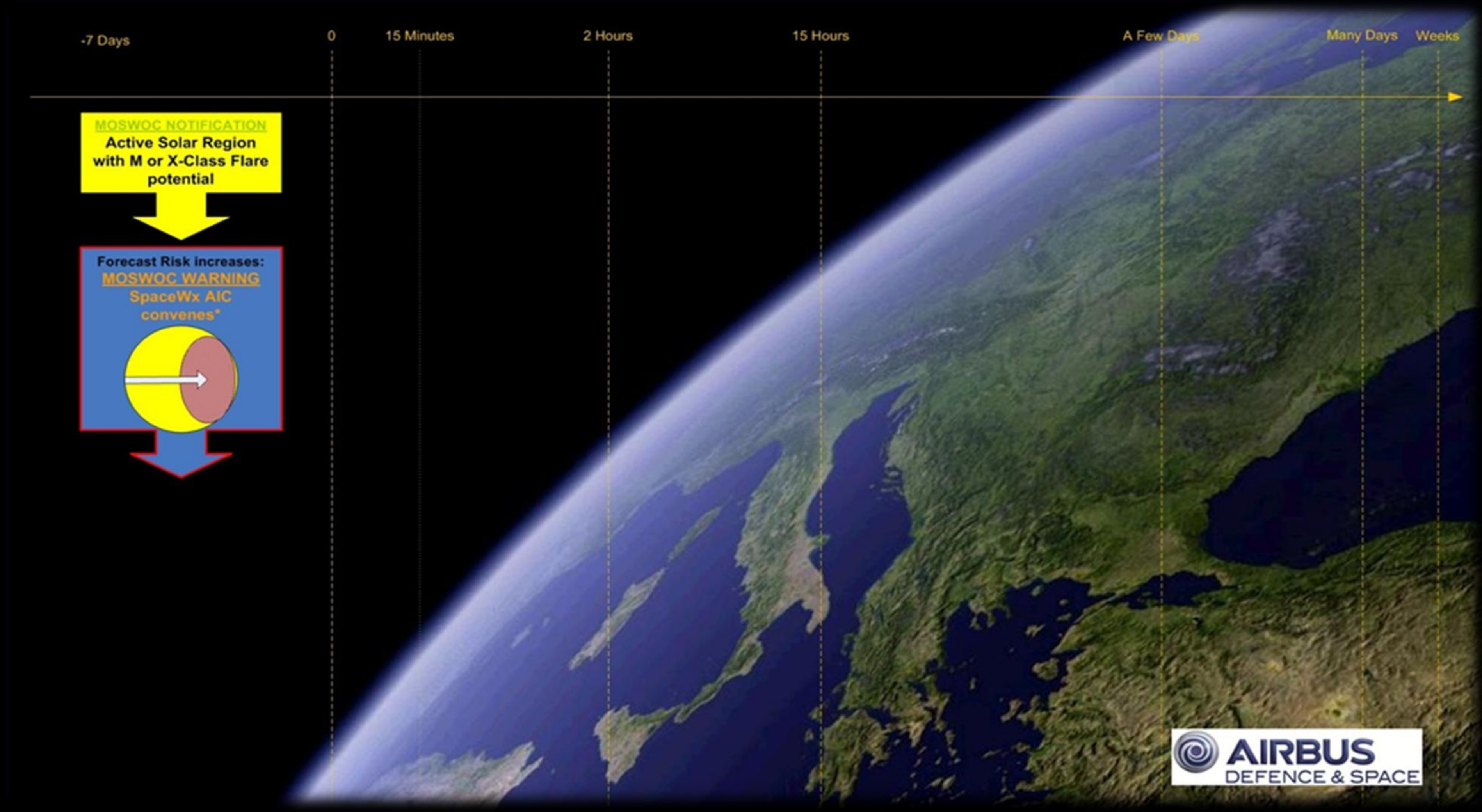
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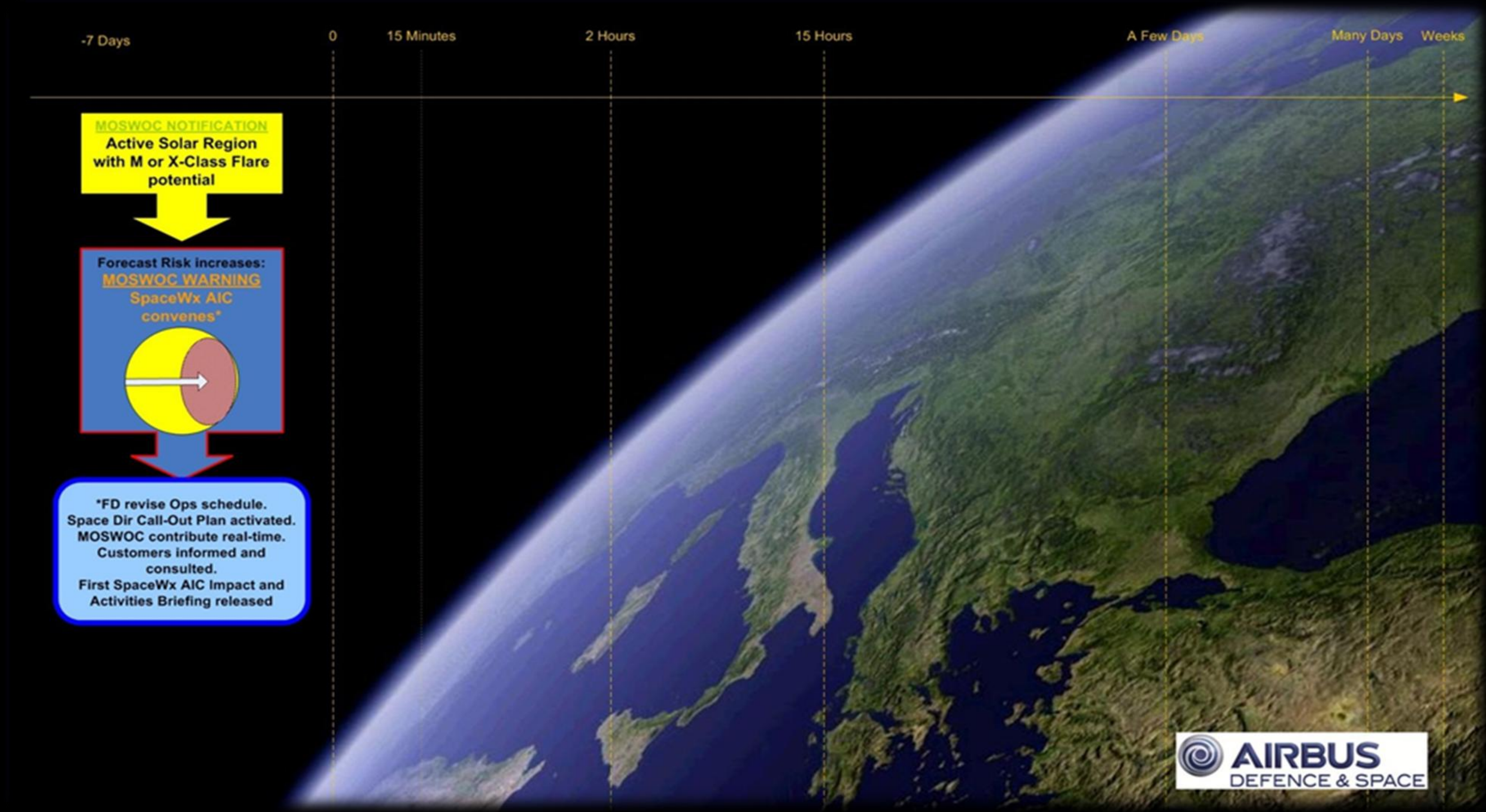
SpaceWx AIC convenes*
AIRBUS DEFENCE & SPACE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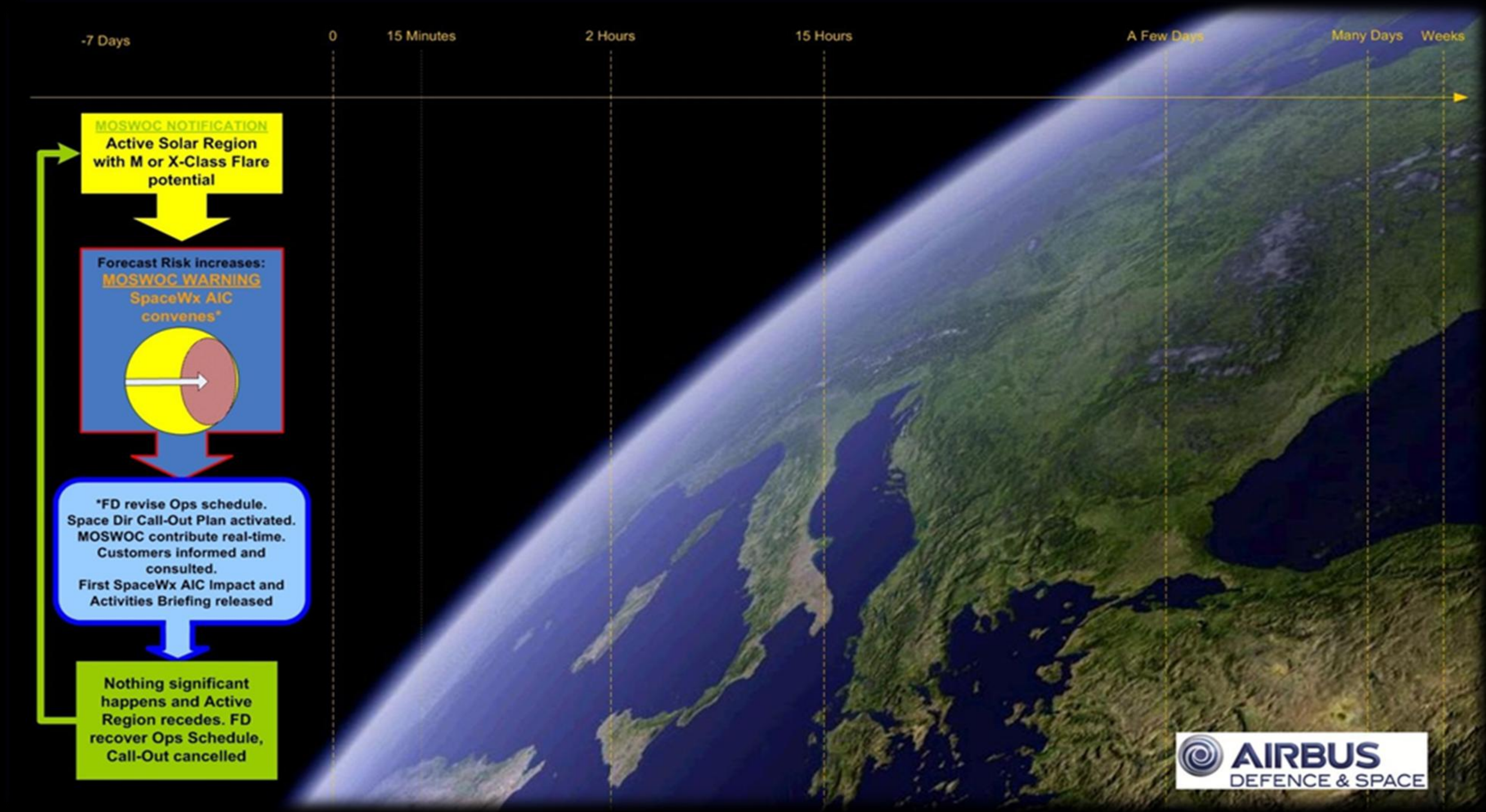
*FD revise Ops schedule.
Space Dir Call-Out Plan activated.
MOSWOC contribute real-time.
Customers informed and consulted.
First SpaceWx AIC Impact and Activities Briefing released
AIRBUS DEFENCE & SPACE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Nothing significant happens and Active Region recedes. FD recover Ops Schedule, Call-Out cancelled
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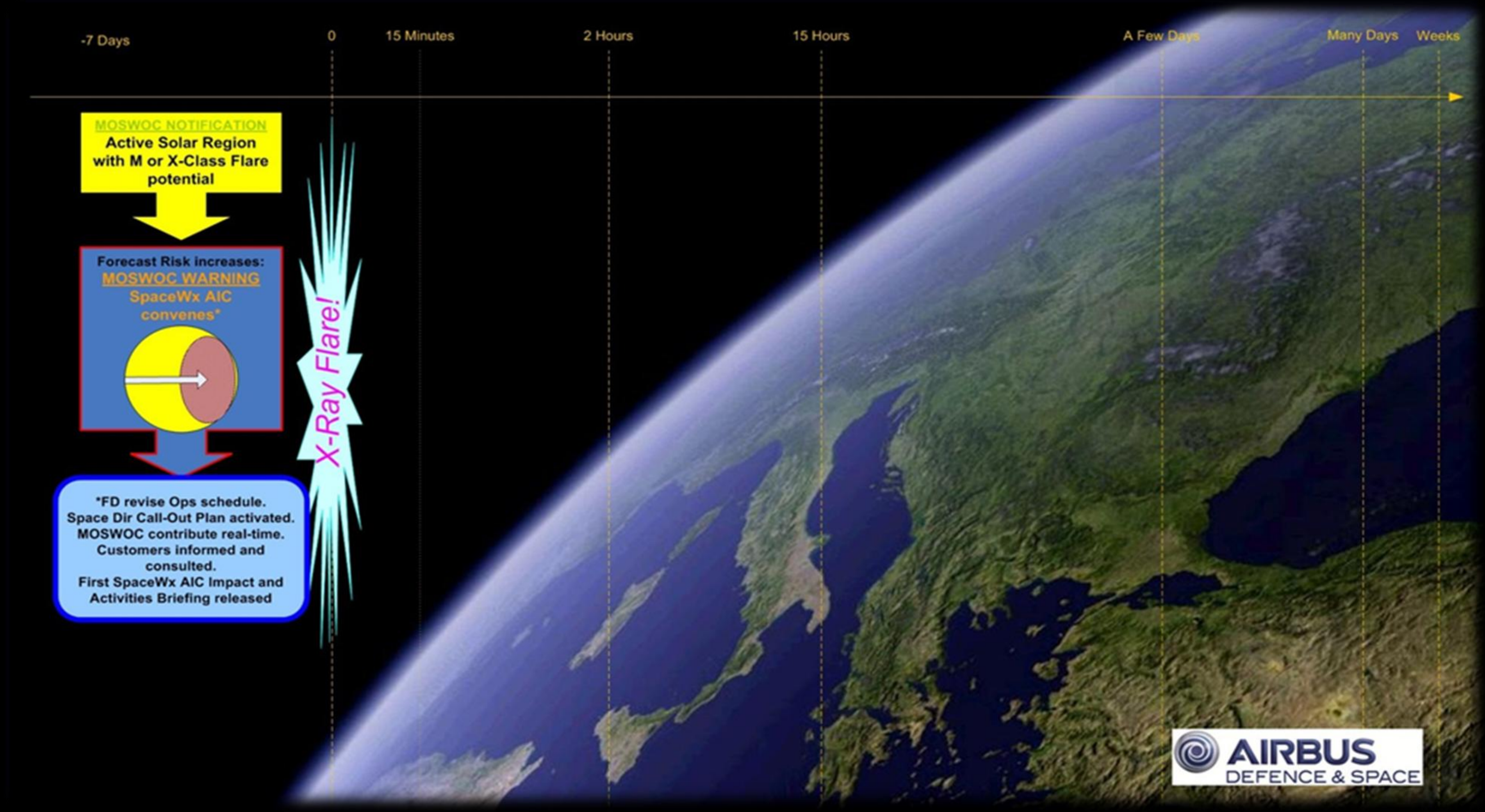






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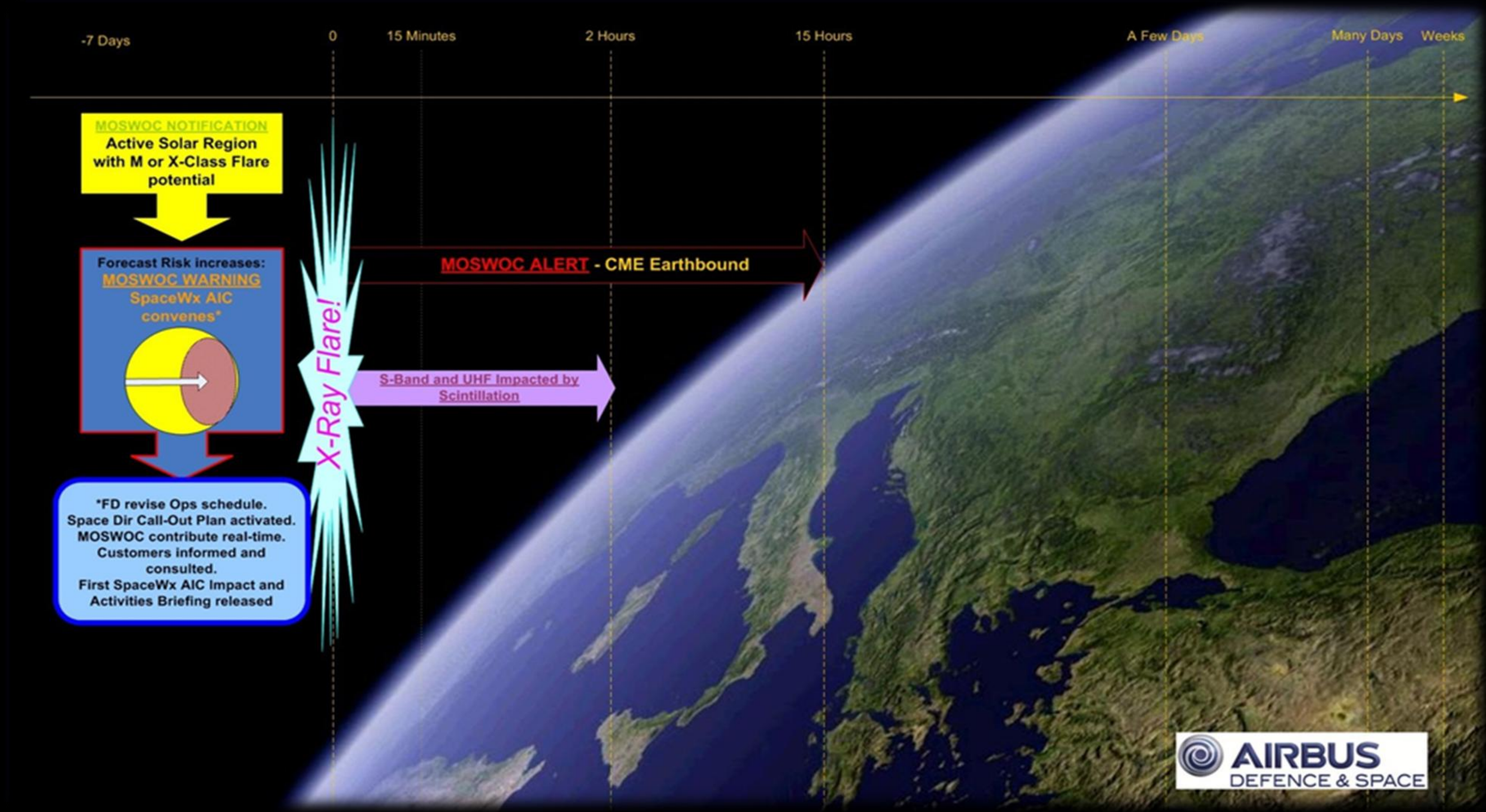






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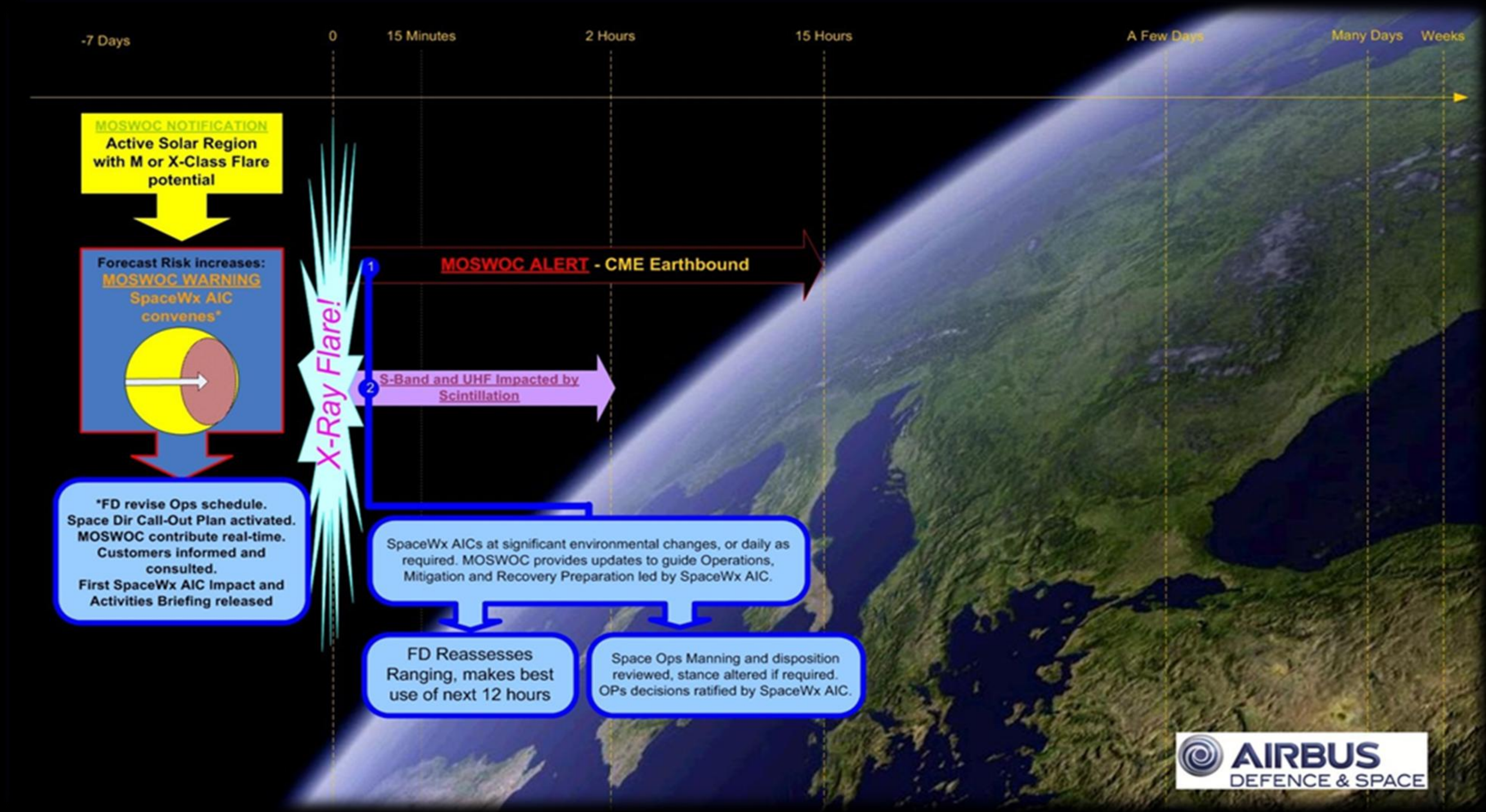






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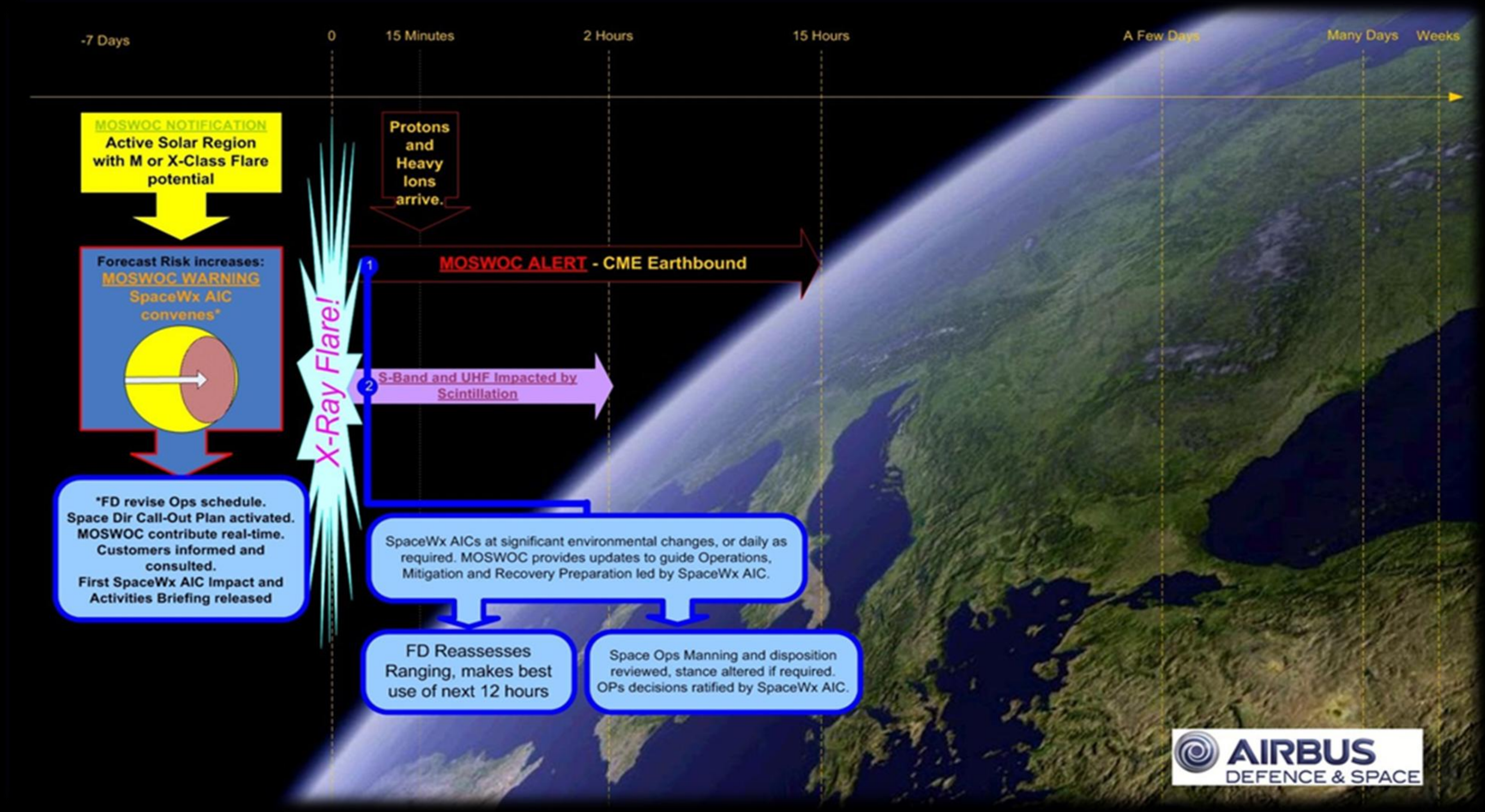






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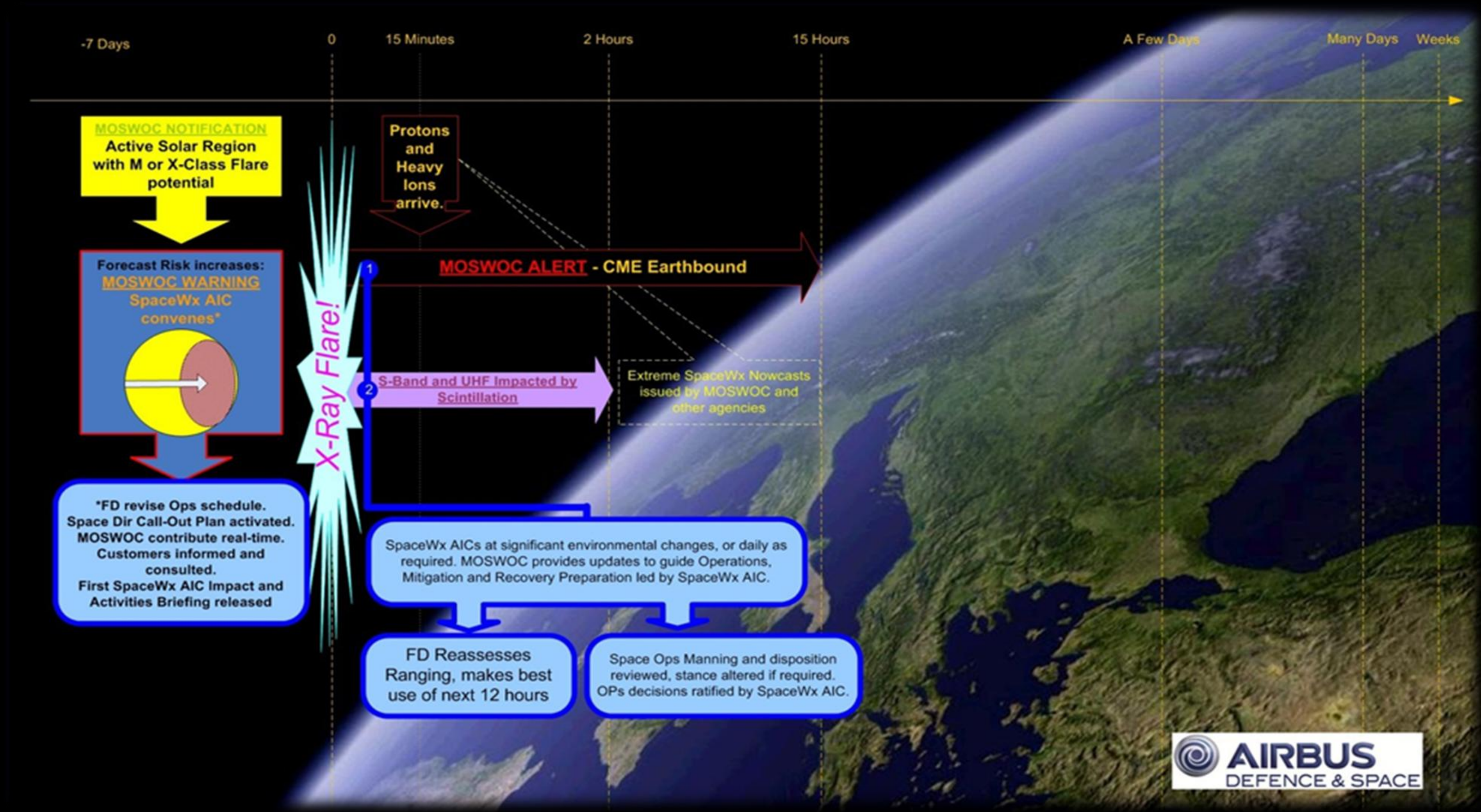
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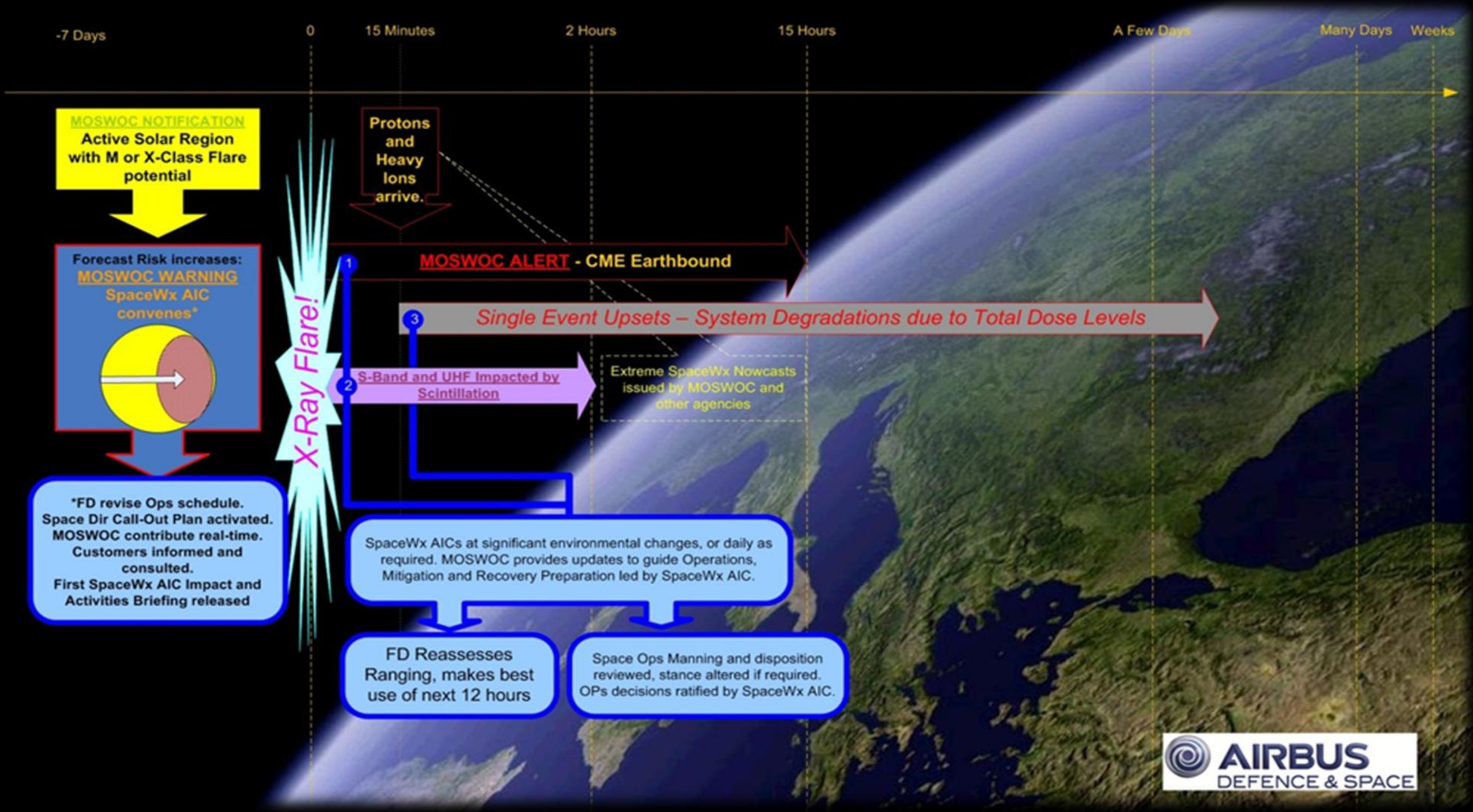
X-Ray Flare!
Protons and Heavy Ions arrive.
1
MOSWOC ALERT - CME Earthbound
2
S-Band and UHF Impacted by Scintillation
Extreme SpaceWx Nowcasts issued by MOSWOC and other agencies
SpaceWx AICs at significant environmental changes, or daily as required. MOSWOC provides updates to guide Operations, Mitigation and Recovery Preparation led by SpaceWx AIC.
FD Reassesses Ranging, makes best use of next 12 hours
Space Ops Manning and disposition reviewed, stance altered if required. OPs decisions ratified by SpaceWx AIC.
AIRBUS DEFENCE & SPACE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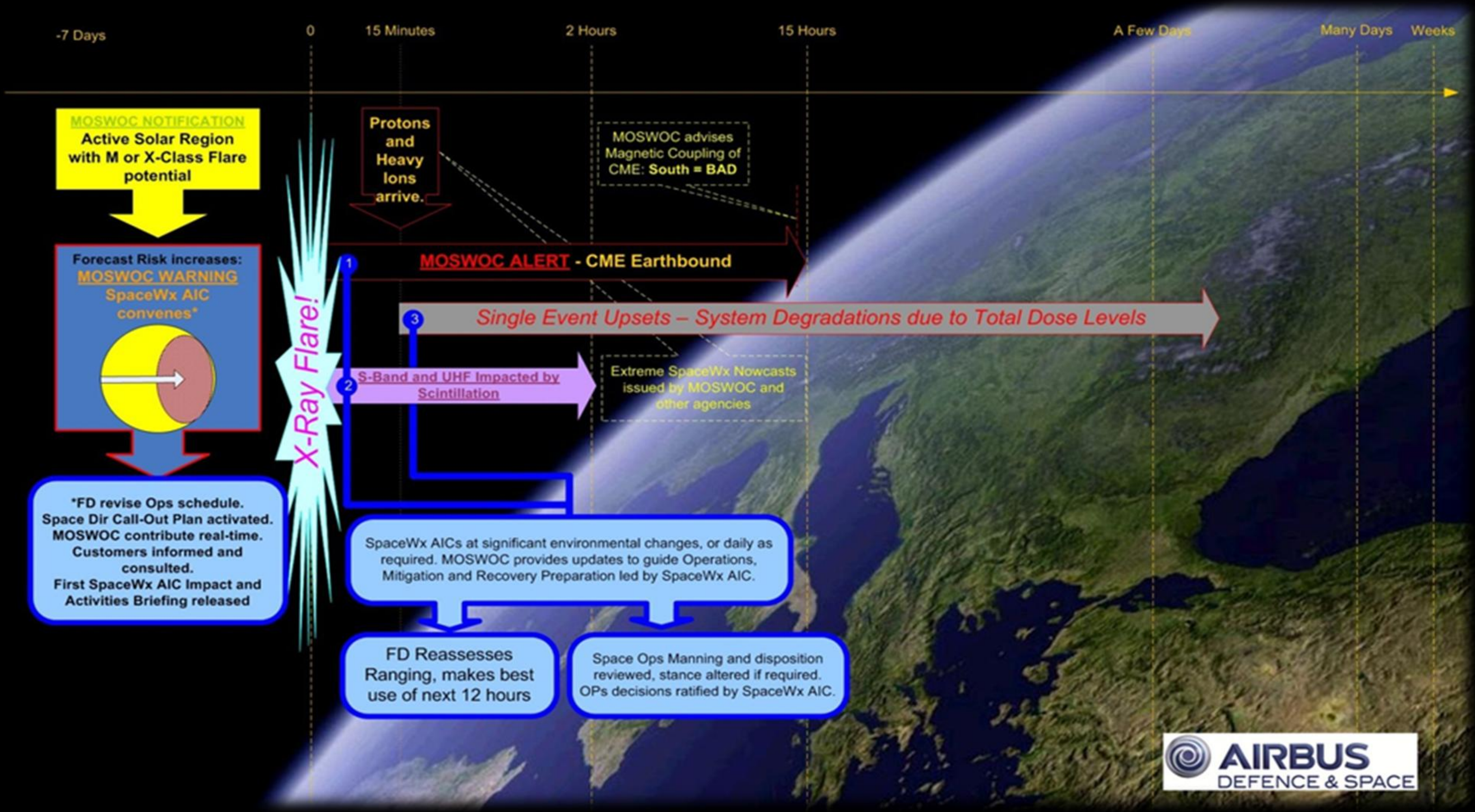

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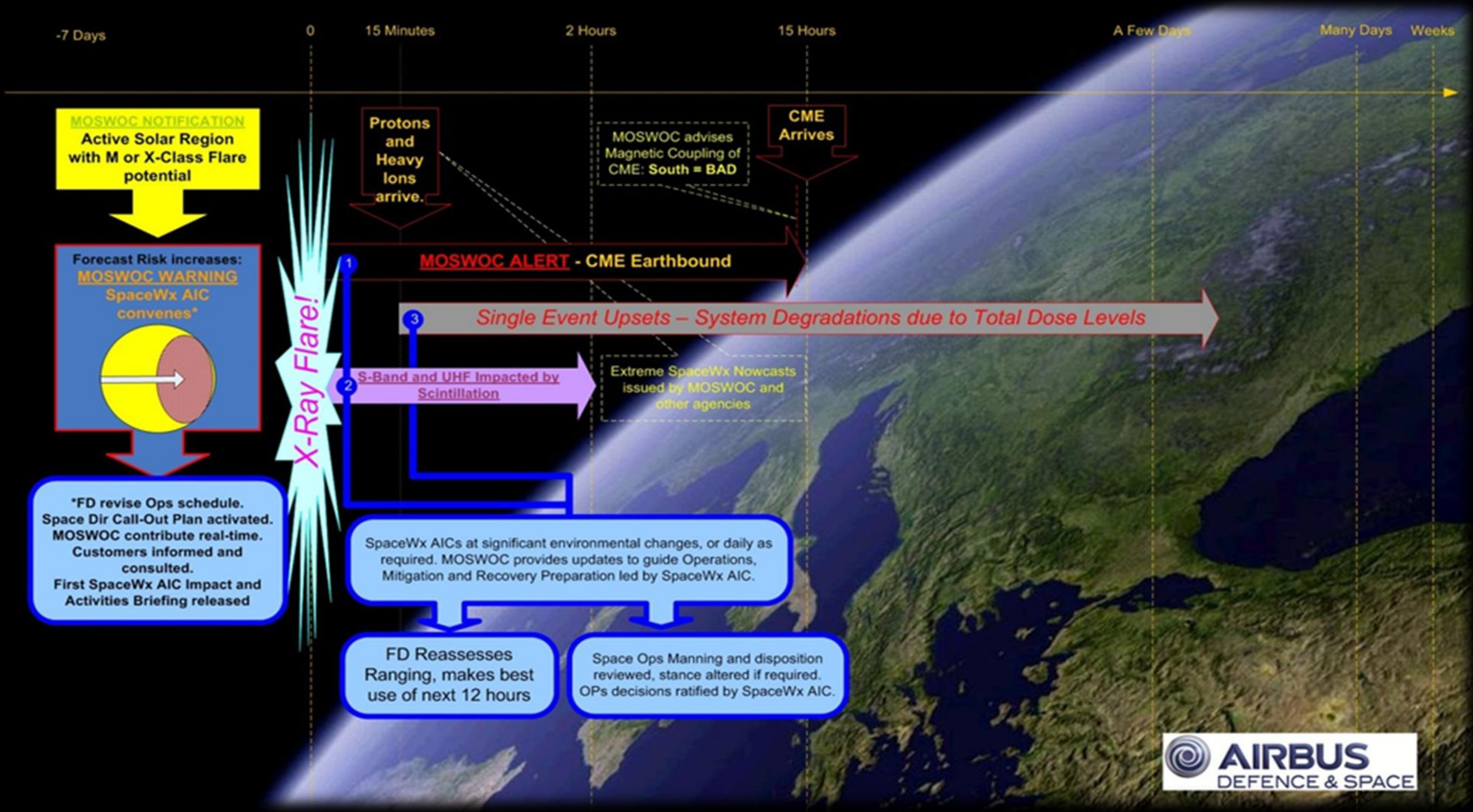






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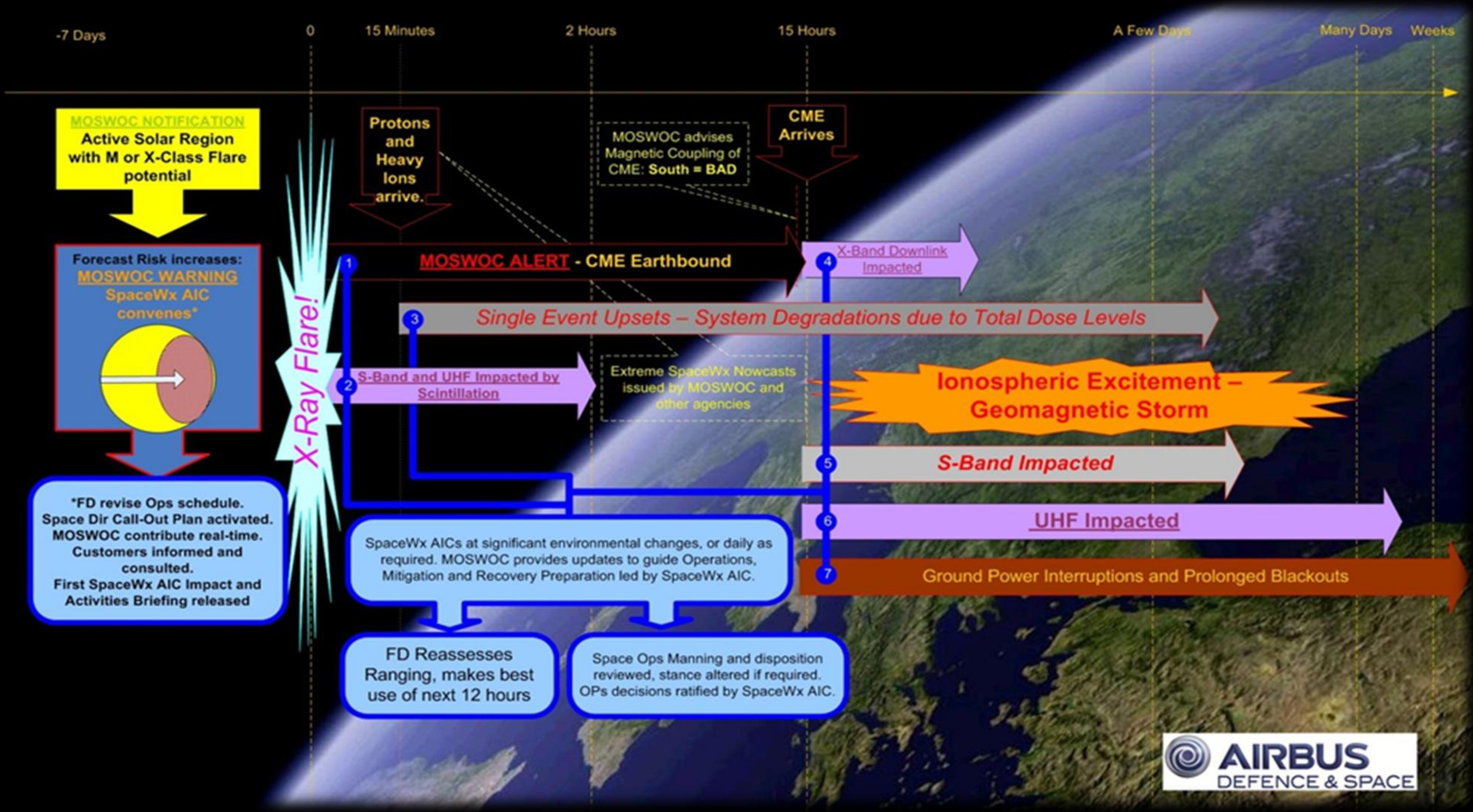






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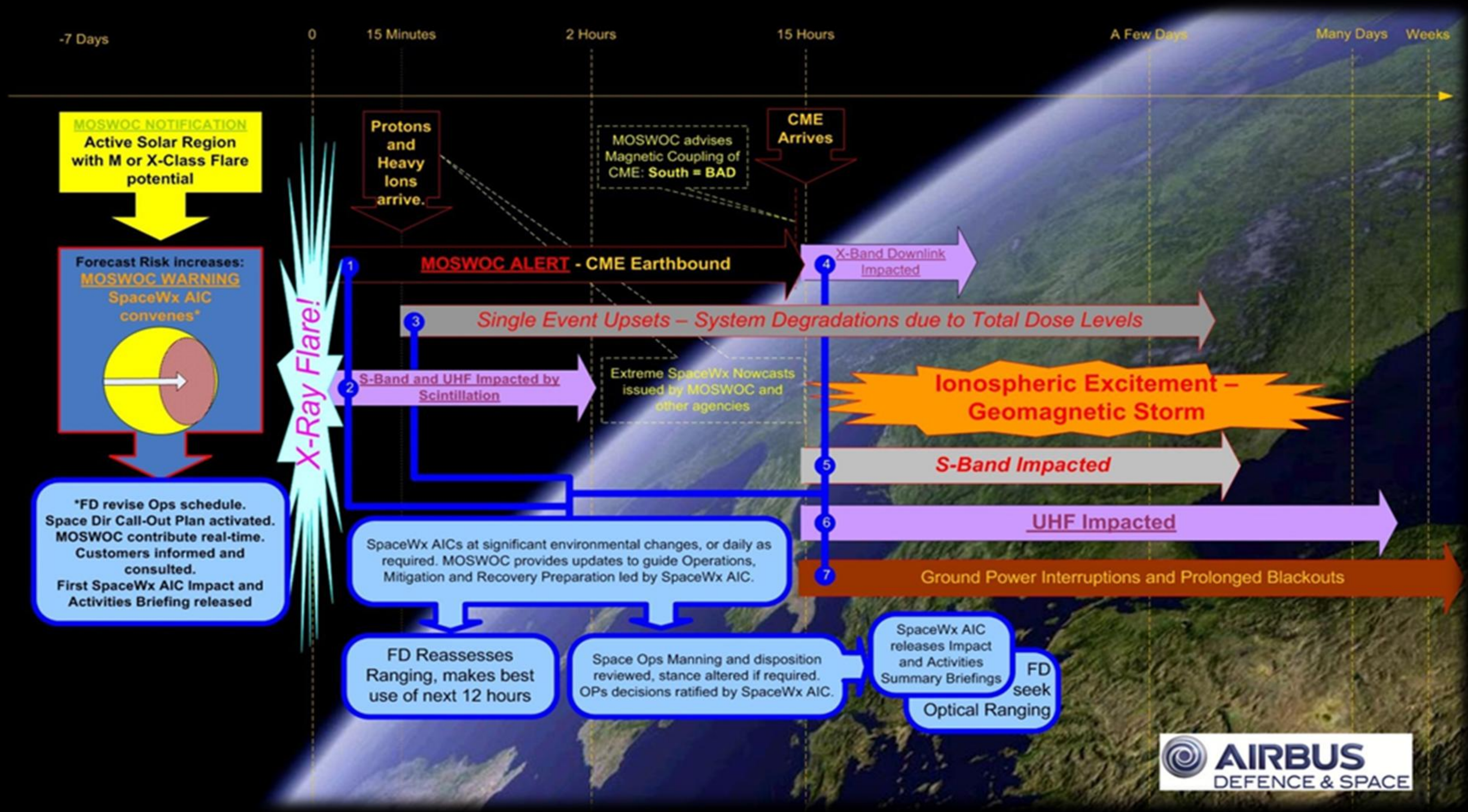
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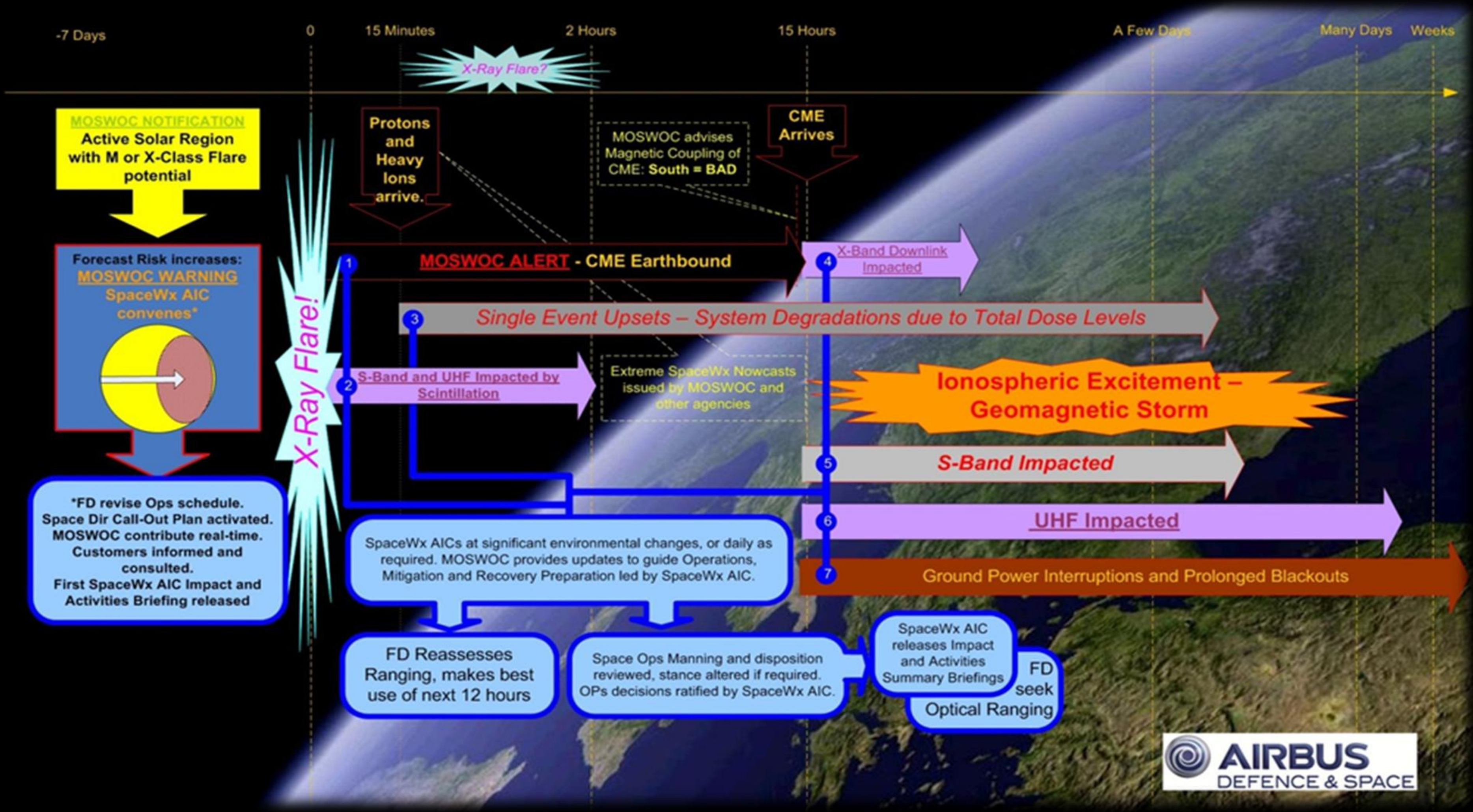
AIRBUS DEFENCE & SPACE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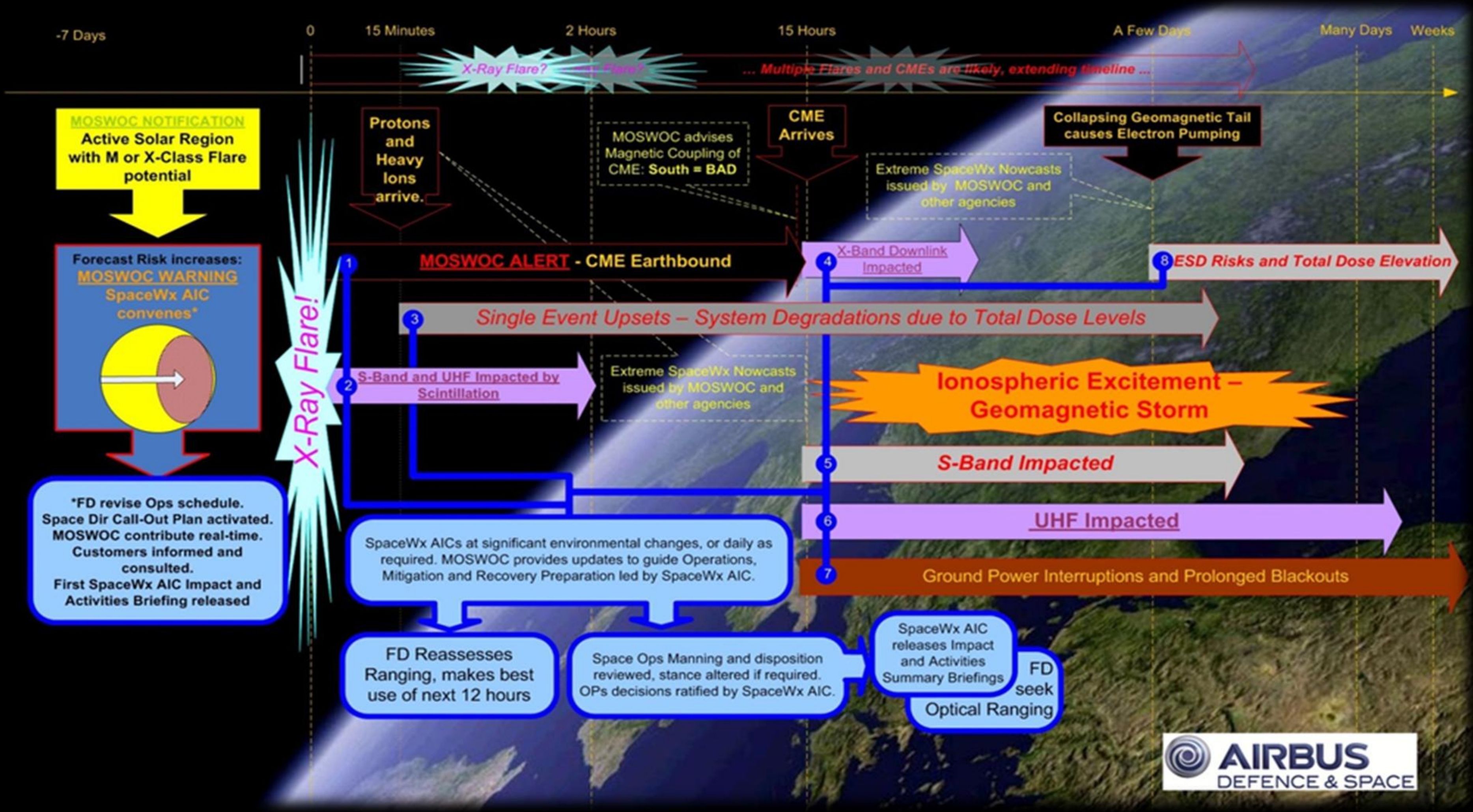
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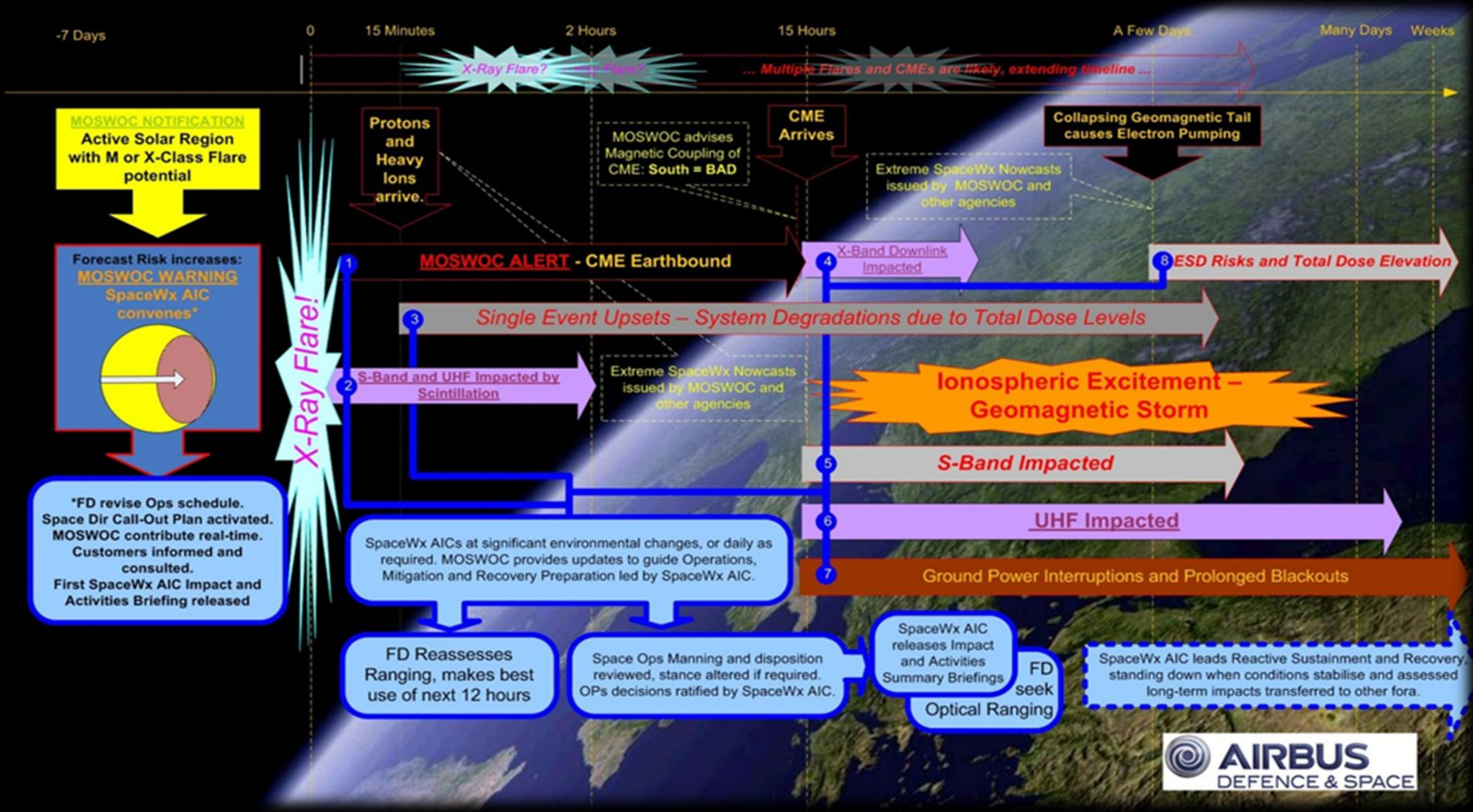
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SpaceWx AIC leads Reactive Sustainment and Recovery, standing down when conditions stabilise and assessed long-term impacts transferred to other fora.
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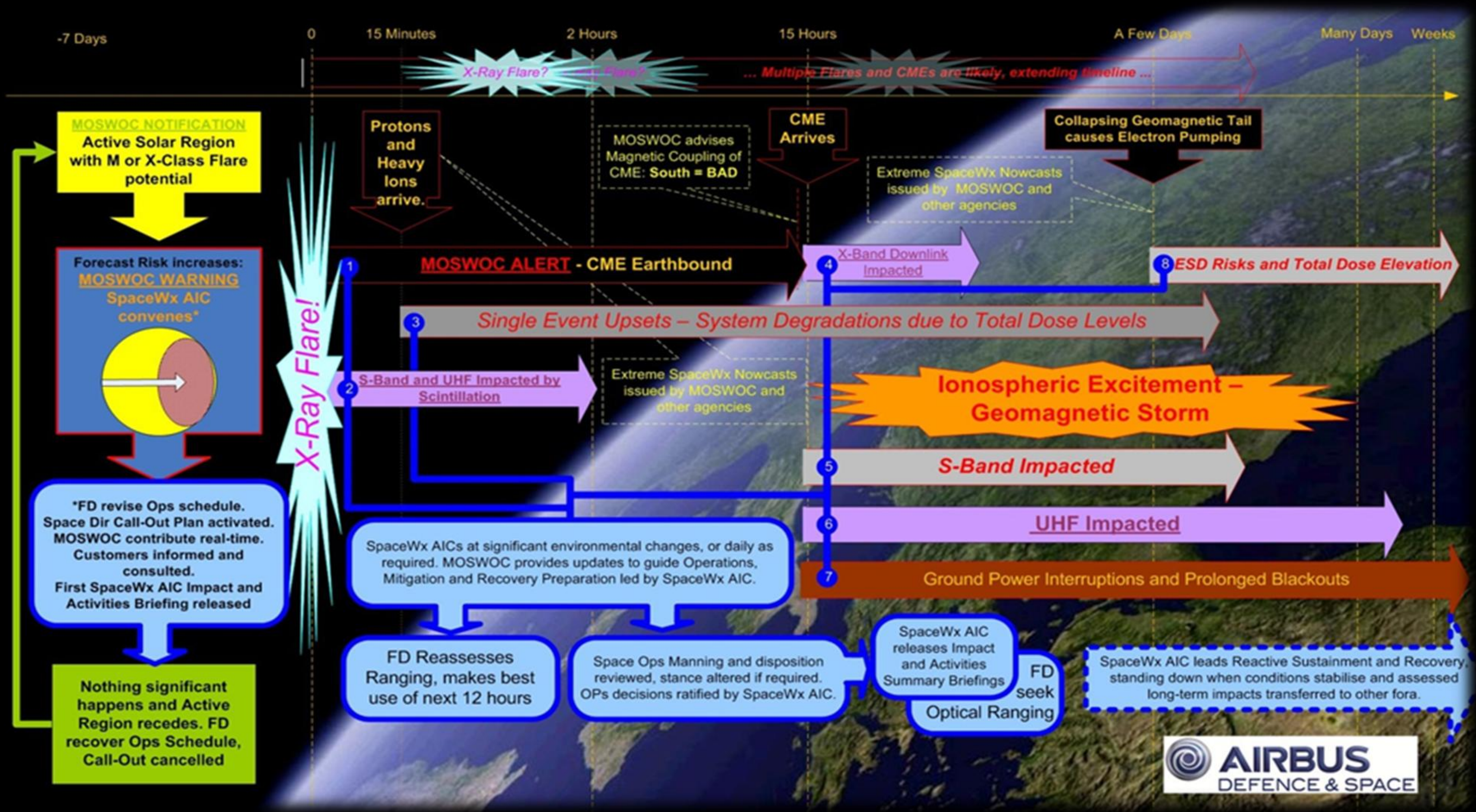




UNCLASSIFIED // OFFICIAL

# … if We Had an L5 Mission






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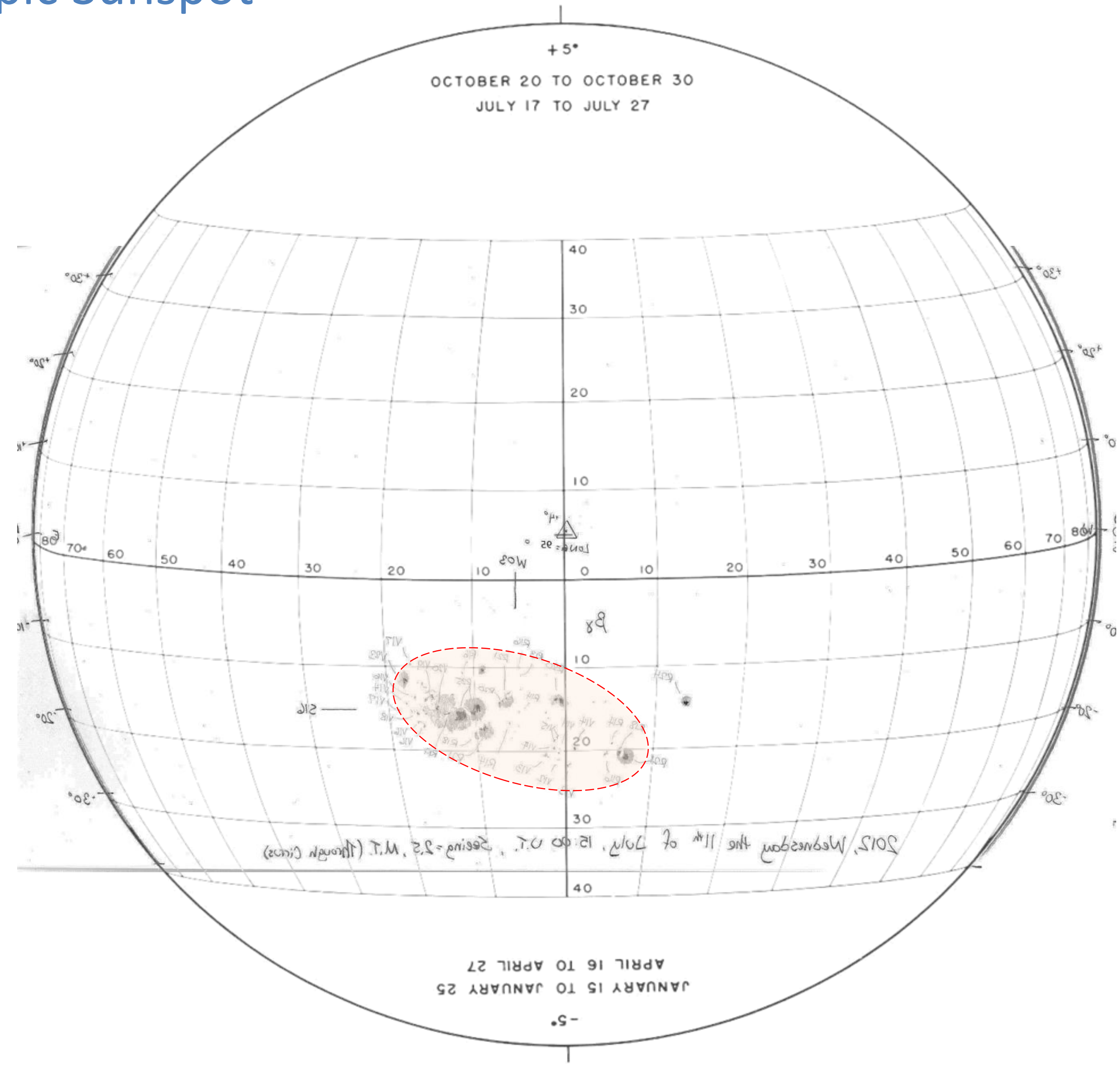
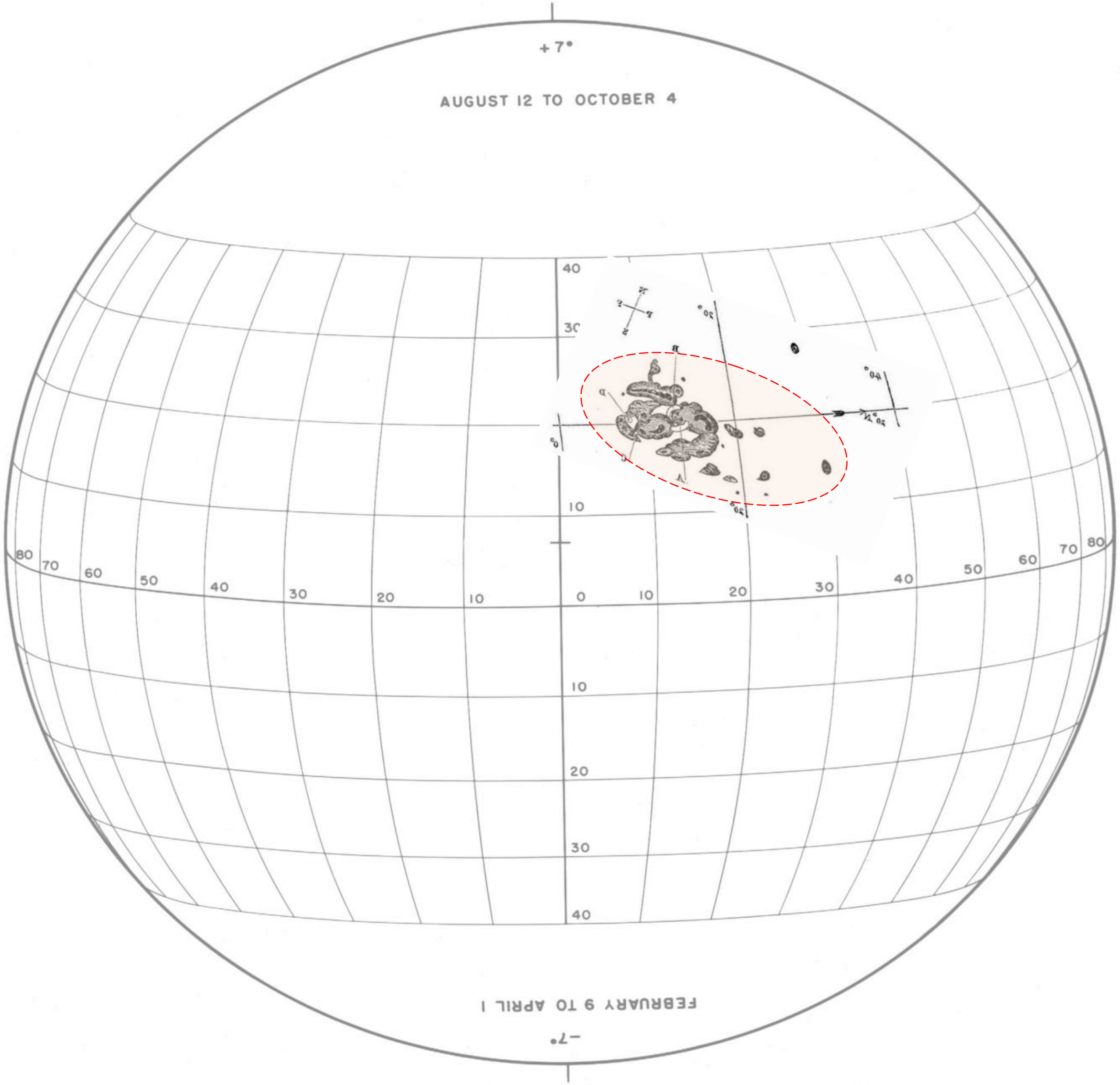
# The Olympic Sunspot



Carrington's Sunspot,
1 Sep 1859




Carrington's Sketch shows a massive sunspot group extending over 30 deg of the solar surface.

The sketch has a low level of detail, suggesting that the resolution of his telescope was insufficient to resolve detail less than 2 deg across.

This sunspot group may therefore have been larger than Carrington was able to record.