Report on the ESA Space-Weather Socio-Economic Study

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Study Objectives

- An *ex-ante study* to assess the economic *costs and benefits* that could be realised from the implementation of ESA's three segments under the Space Situational Awareness (SSA) programme: SWE, NEO, and SST.
- The benefits of the ESA services were measured for sectors of interest (domains) by calculating how the planned ESA services will help *mitigate adverse impacts* of space weather events, near earth objects entering the atmosphere and space debris collisions.
- The resulting avoided costs and additional revenues were considered alongside the estimated costs of launching and operating these programmes.

Assumptions of the CBA for the SWE segment

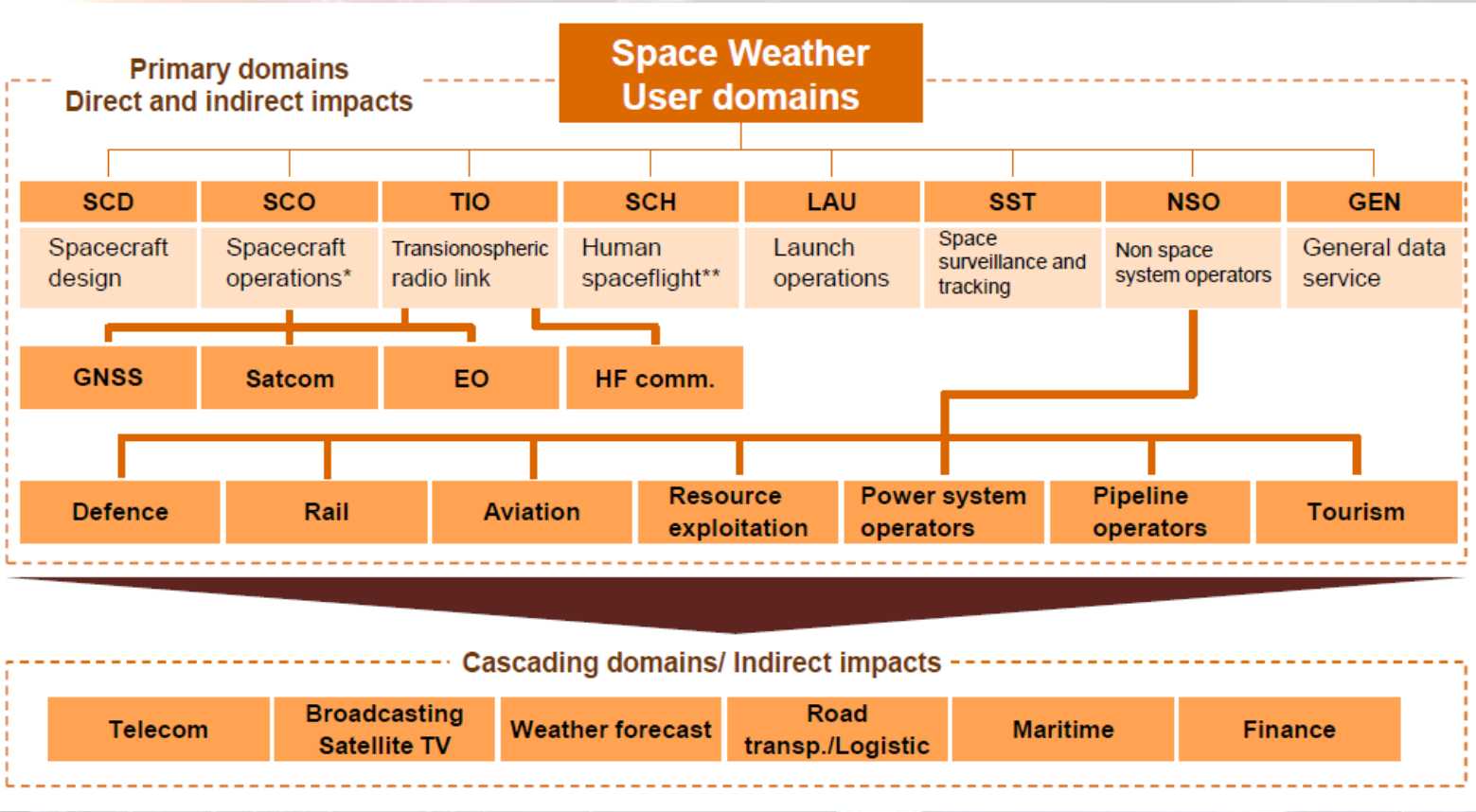
Do nothing scenario:

- No investment to ESA SSA SWE system
- No substantial improvements over service status today
- No coordinated development of measurement system

Do ESA SSA Programme:

- Coordinated development and validation of end-to-end models and applications
- Improved SWE forecasting capability
- Ensured availability of the measurement data
- Development of new capability through international collaboration:
  → combination of L1 and L5 data

ESA SSA SWE User Domains

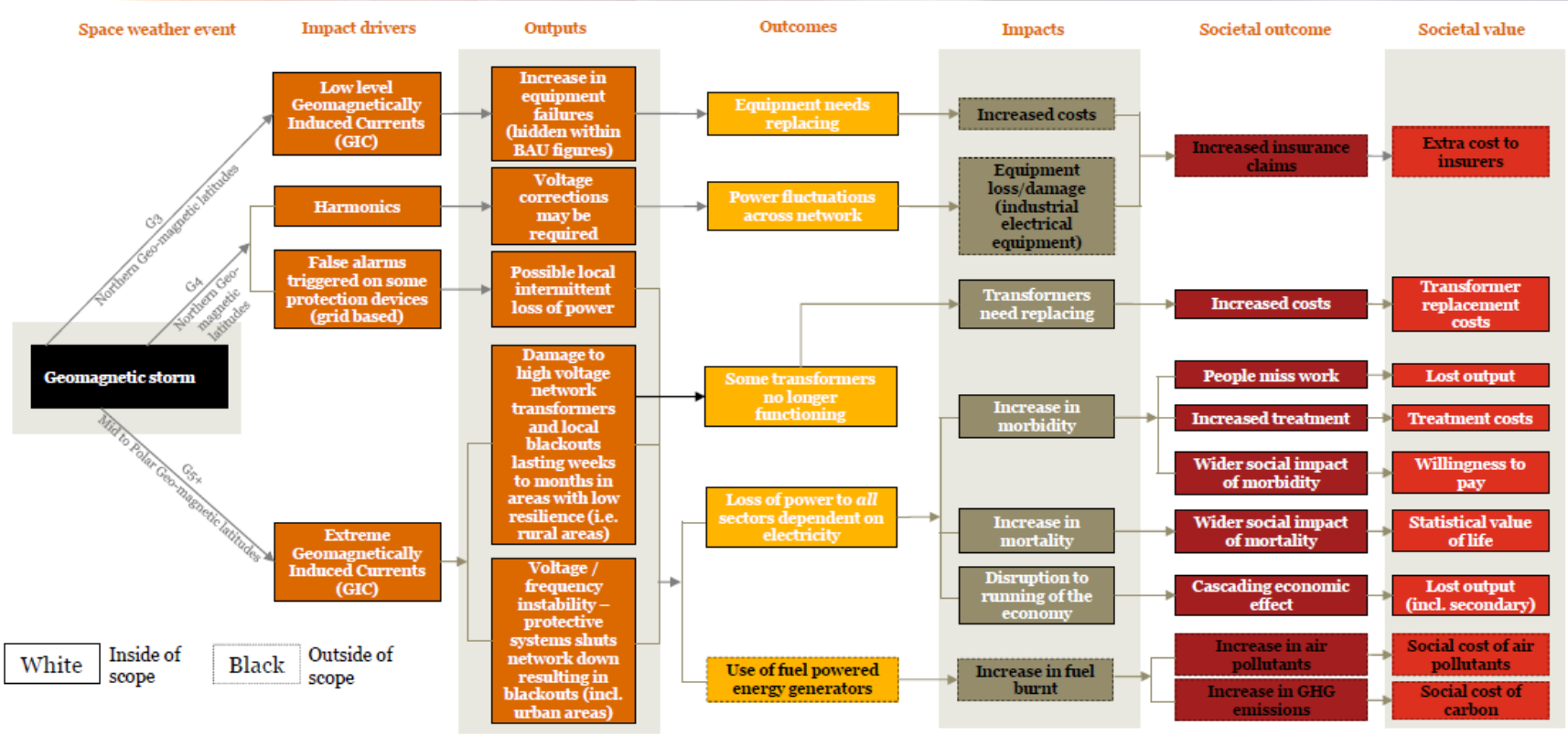


Assumptions about SWE Events

	Geomagnetic storms1			Solar radiation storms			Ionospheric disturbance		
	Intensity	Frequency	Single event duration	Intensity	Frequency	Single event duration	Intensity	Frequency	Single event duration
Extreme events2	G5+	~1 in 100 years	3 days	S5+	~1 in 100 years	2/3 days	R5+	~1 in 100 years	3-6 hours
Major events3	G5	~1 in 2-30 years	12/18 hours	S5	~1 every 10 years	1/2 days	R5	~1 every 10 years	3-4 hours
Strong events	G3-G4	~ 10-20 per year	6/12 hours	S3-S4	~ 1 per year	8/20 hours	R3-R4	~20 per year	Up to 2 hours

1. Includes Enhanced outer radiation belt
2. "Carrington" 1859 scale event
3. Up to and including Quebec 1989 level events

SWE Impact Pathways



Results of the CBA for the SWE segment

Cost/Benefit	Do nothing scenario	Do ESA scenario	Value added of ESA services
User domain benefits			
Satellite operations	- €293 M	- €267 M	€26 M
Launch operations	- €0.3 M	- €0.1 M	€0.2 M
Resource exploitation	- €327 M	- €135 M	€192 M
Power grids operations	- €5,771 M	- €4,546 M	€1,225 M
Aviation	- €3,312 M	- €3,066 M	€246 M
Logistic/Road transport	- €3,432 M	- €2,888 M	€544 M
Investment benefits			
GDP impact	None	€952 M	€952 M
Total Benefits (b)	- €13,135 M	-€9,950 M	**€3,185 M**
Programme Costs (c)	None	- €529 M	**- €529 M**
Total Net Benefits	- €13,135 M	- €10,479 M	**€ 2,656 M**
	Benefit / Cost ratio (b/c)		**6**

Example of benefits: Aviation

Impact	'Do nothing scenario'	'Do ESA scenario'	Benefits of ESA services for Aviation
Increased financial cost (delayed flight)	- €973 M	- €804 M	€169 M
Value of time (delayed flight)	- €396 M	- €319 M	€77 M
Total Net Benefits	- €3,312 M	-€3,066 M	**€246 M**

- The benefit for aviation from the ESA SWE services derives from an increased certainty regarding on-going space weather phenomena.
- This increased certainty enables airline operators to *reduce the delay time for grounded aircraft by 1/3, from an average of 3 hours to 2 hours.*

Qualitative benefits from SSA SWE development

Macro categories	Qualitative benefits
Strategic	• Increase in autonomy with independent SWE data • Equal partner in data exchange agreements internationally • Coordinate design and development of an operational SWE system • Push for advances in solar science and Sun-Earth interaction understanding • Development of end-to-end modelling capability
Economic	• Positive impact on European economy • Enabling of downstream third-party business opportunities
Societal	• Improved safety of the European infrastructure and services (space systems, human space flight, aviation, transport, power systems…) • Improved safety of human life (navigation, radiation environment,…) • Reduction of morbidity and mortality due to prolonged electrical blackouts • Reduced loss of time in road and rail transport, aviation, …
Environmental	• Reduced risk and faster recover from spill-over from underwater oil wells • Reduced green house gas emissions from alternate flight routes and levels

Extreme SWE event impact estimates

Domain	2016 (year 1)	2024 (year 9)	2032 (year 17)
Spacecraft design and operations	- €912.9 M	- €1,123.2 M	- €1,389.4 M
Launch operations	- €0.008 M	- €0.037 M	- €0.051 M
Aviation	- €6,635.6 M	- €11,139.8 M	- €18,701.5 M
Resource exploitation	- €197.5 M	- €234.9 M	- €279.5 M
Power system operators	- €5,630.5 M	- €6,364 M	- €7,195.2 M
Road & Transportation	- €1,595.4 M	- €1,783 M	- €1,992.8 M
TOTAL	- €14,971.9 M	- €20,644.9 M	- €29,558.4 M
Estimated savings with ESA SSA SWE	2,500 M	3,500 M	5,000 M

Lessons Learned

- **CBA study is more challenging than it may appear**
- Understanding the domains of impact is usually incomplete
  => many assumptions are necessary
- Collecting information from stakeholders is harder than expected
- Many stakeholders may not yet know how to utilise SWE data
- Statistics for SWE specific impacts are limited
  - Moderate event impacts are not well recorded
  - Strong and extreme events are rare
- Quantification of non-financial benefits is difficult
- Estimating benefits from individual SWE investments is very difficult

=> CBA requires several iterations + international collaboration

THANK YOU

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