Ex-ante cost benefit analysis of the Space Weather Element of the ESA SSA programme

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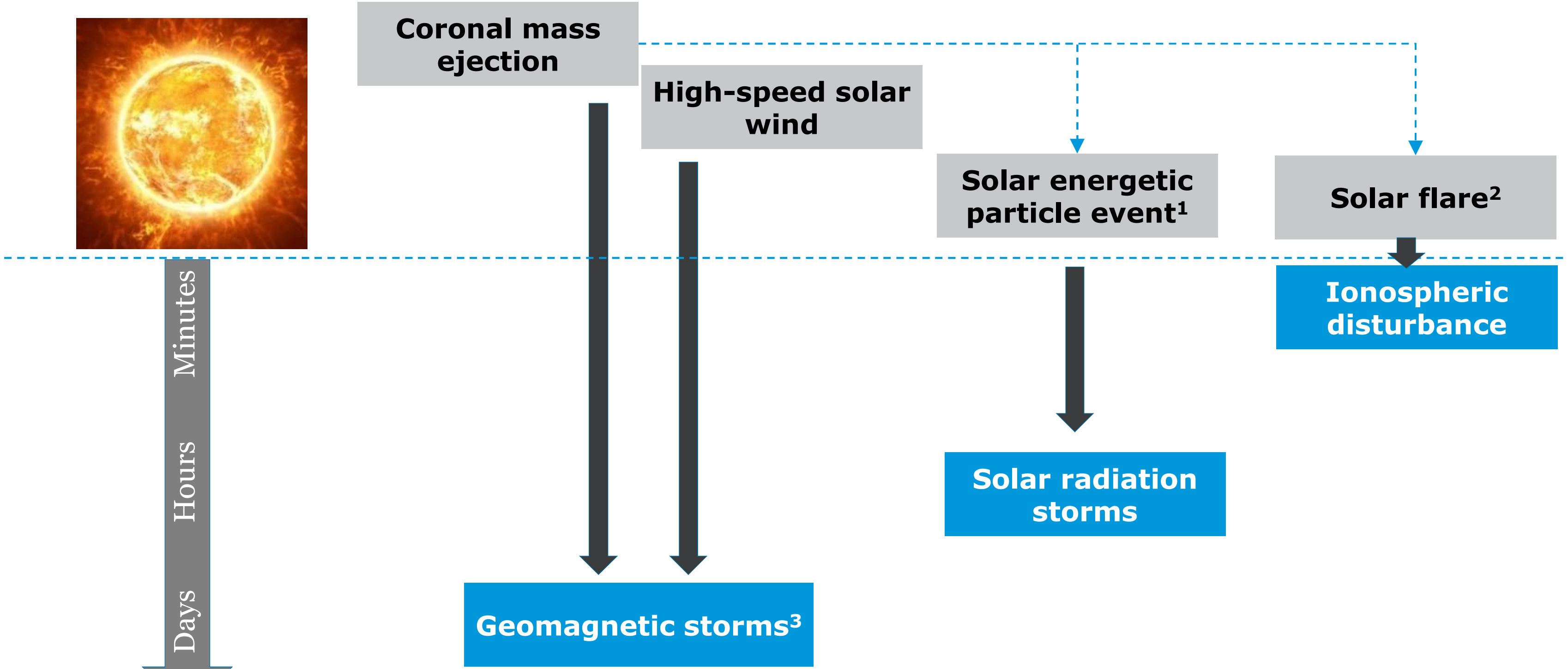
Objectives of the SSA CBA study

- 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.
- **This presentation focuses on the SWE element only**
- 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.
- The resulting avoided costs and additional revenues were considered alongside the estimated costs of launching and operating these programmes.

Large GS following a CME are predictable with at least 12 hour notice, but with low accuracy



1. SEPE might be generated minutes after a CME or can develop independently of a CME. SEPE are difficult to forecast, but onece the phenomena is observed its evolution can be forecasted with (under consolidation) proxies and models. Current SEPE phenomena forecast based on judgment call, not on models.

2. Solar flare might be generated minutes after a CME or can emerge independently of a CME. ESA is developing model to forecast flares based on observation. Models are immature, current forecasts are qualitative with a low level of accuracy.

2. Includes Enhanced outer radiation belt

Geomagnetic storms are the most frequent solar activities generating majority of impacts on Earth

	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

Assumptions of the CBA for the SWE segment

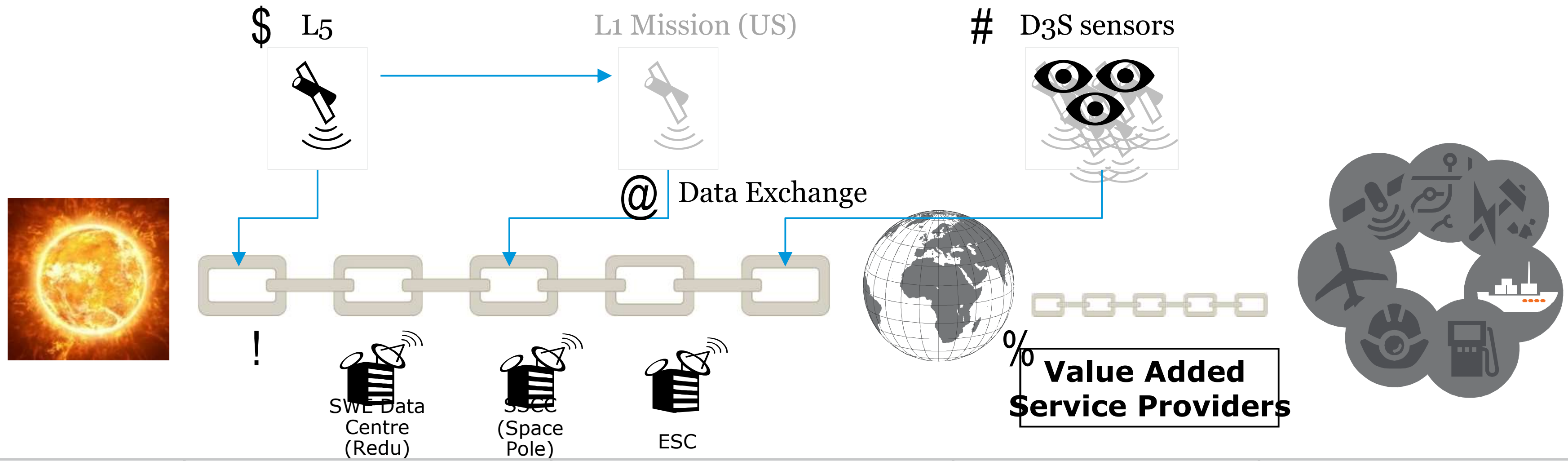
Do nothing scenario:

- 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

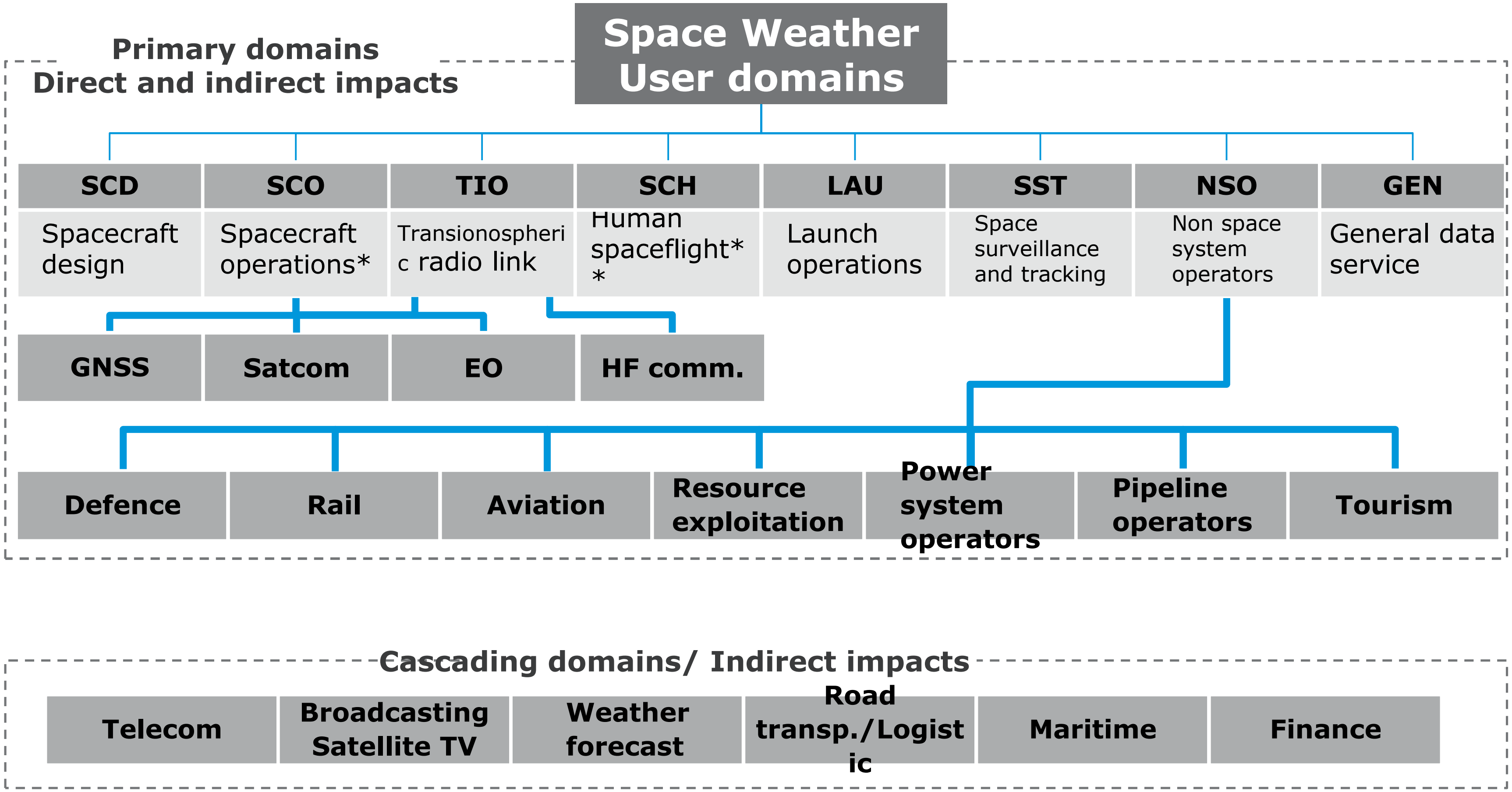
ESA intends to deploy a system made-up of 5 main elements



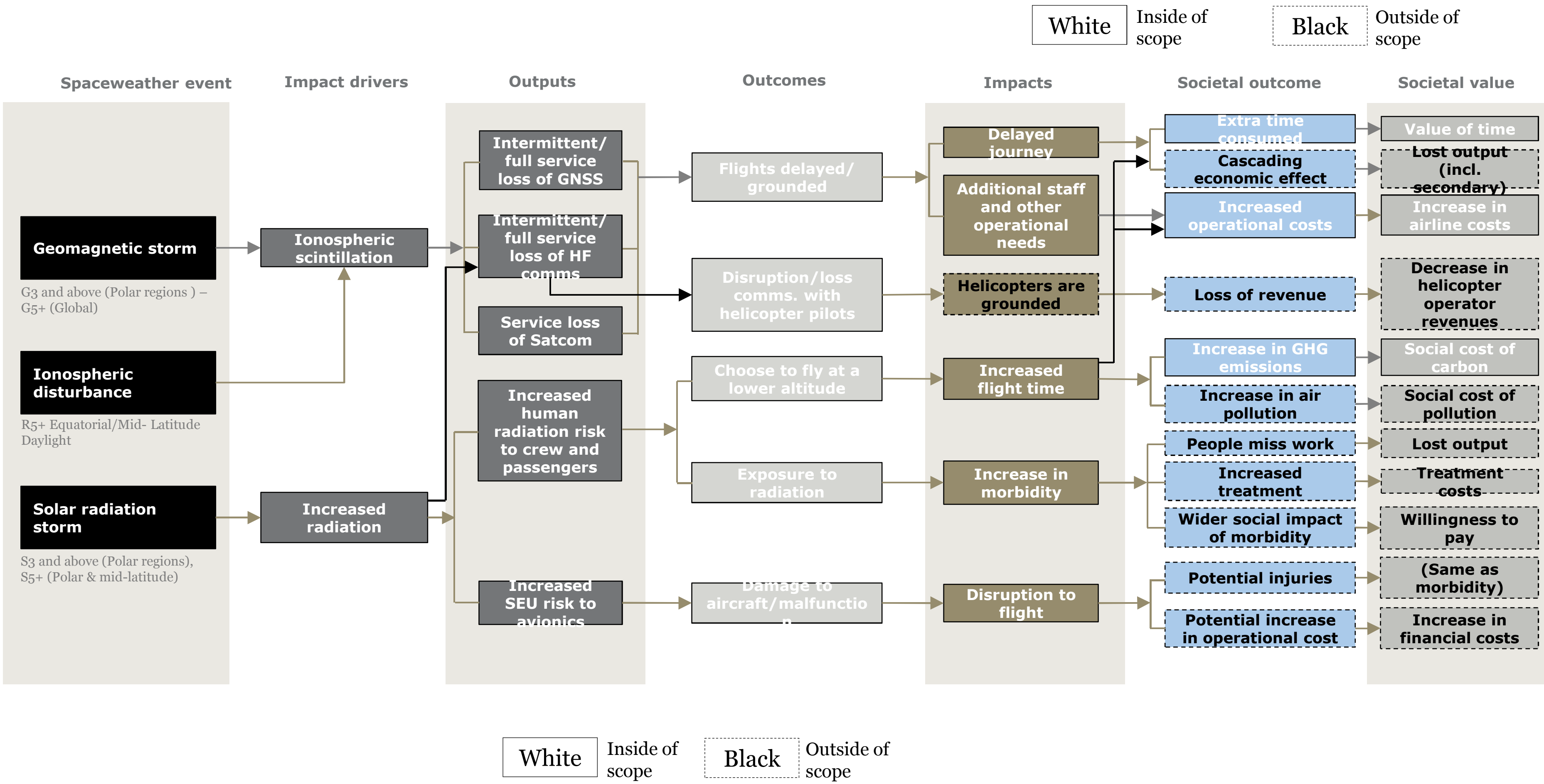
Do Nothing	!	• G-storm Forecast (24 h) • Storm characterisation (in-situ) • Now & Post Cast (all storms) @	#	$

Do ESA	• Early forecast & characterisation:
	  • CEM and G-storm
	  • SEPE and S storm
	  • Flare and R storm
		• Model validation	• Model validation
			• Space environment investigation & understanding
				• Model validation
				• Earlier forecast (all storms 5/7 days)
				• Early storm characterisation (all storms)

ESA identifies 8 domains suffering direct SWE impacts with cascading effects on other domains



Example: Aviation – Impact pathway



In case of extreme storms (G/R/S5+) all flight are expected to be grounded for 3 hours in average Benefit: 1/3 reduction of delay time for grounded aircrafts

Number of flights per year

6.4 M

Average cost of a 3h flight delay

0.05 M€

Number of passenger per year

958M

Do Nothing Scenario	
Impact	- €1,369 million
Do ESA Programme	
Impact	- €1,123 million
Do ESA Programme benefits	
Benefit	**€246 million**

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.*

Main limitations include assumptions passenger growth and fuel efficiency being constant

Limitations of economic analysis

Passenger growth

- Total passenger number growth was assumed constant. In reality the growth rate is likely to fluctuate year-on-year, there could be upwards pressure and downwards pressure on passenger number growth for different reasons. As it is difficult to know how this will change, a constant rate is preferred

Fuel efficiency

- Fuel efficiency of an airplane will not improve over the duration of the study period. In reality fuel efficiency is likely to change over time, but it could move up or down. So keeping it constant seems less spurious.

Value of time

- The value of time for a passenger is assumed to be the same for all passengers. The reality is that the value of time for a passenger will vary for every single passenger, with a number of factors contributing as inputs to this value for each individual. This would be far too complex to model. So one rate is used for everyone

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**

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

SWE architecture deploys along the SWE value chain, creating opportunities for VAS provider

esa

SWE Sensors and centers manufacturers

- Sensors design, develop, & manufacturing/ready for use
  - Manufacture L1 satellite, and its ground segment
  - Launch L1 satellite
  - Manufacture Magnetometers, etc
- Data Center develop, build
  - Build center real estate
  - Design, develop computer/SW/databases
  - (…)
- Service centers
  - Build center
  - (…)

SWE sensors & data centers operators

- Sensors operators
  - Operate satellite, perform TT&C
  - Magnetometer maintenance, etc
  - (…)
- Data Center operator
  - Data tasking and acquisition
  - Data processing and archiving
  - (…)

SWE main service provider

- Conduct research of solar and terrestrial physics
- Develop techniques for forecasting
- Analyse data to translate into valuable information
- Elaborate daily space weather bulletins
- Issue warnings and alerts
- Distribute analysed data
- (…)

SWE value added service providers

- Perform further specialists data analysis
- Tailor info/data to meet specific user needs
- Develop handbooks for users' protection
- Develop verification test procedures
- Develop algorithms and SW tools
- Provide forecasts services
- (…)

SWE users "affected industry"

- Take informed decision to apply/not apply an operational mitigation measure
- Conduct post-storm analysis on its assets
- Acquire knowledge to modify ops measure
- Acquire knowledge to feed SWE user requirements
- (…)

SWE Service Coordination Centre (SWCC)

SWE Sensors and centers manufacturers → **Space segment operator / Ground sensors operators** → **SWE data centre** → **Expert Service Centres** → **End users**

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