The Road to 72-120 hr forecasting and SEEMS, the Space Environmental Effects Monitoring System

Briefing to the

National Space Weather Panel

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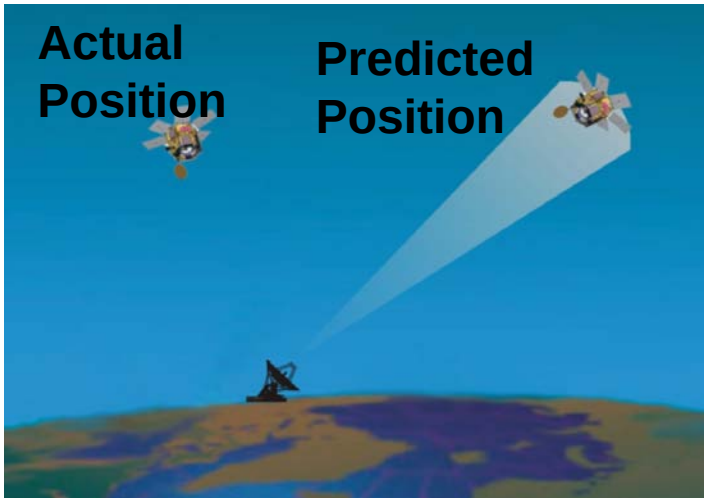
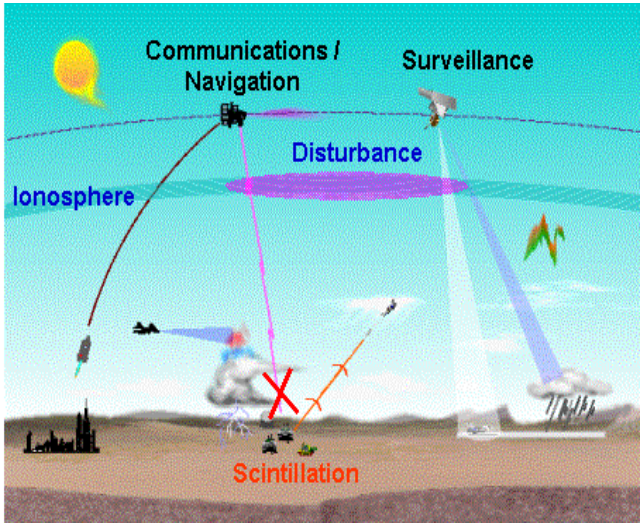
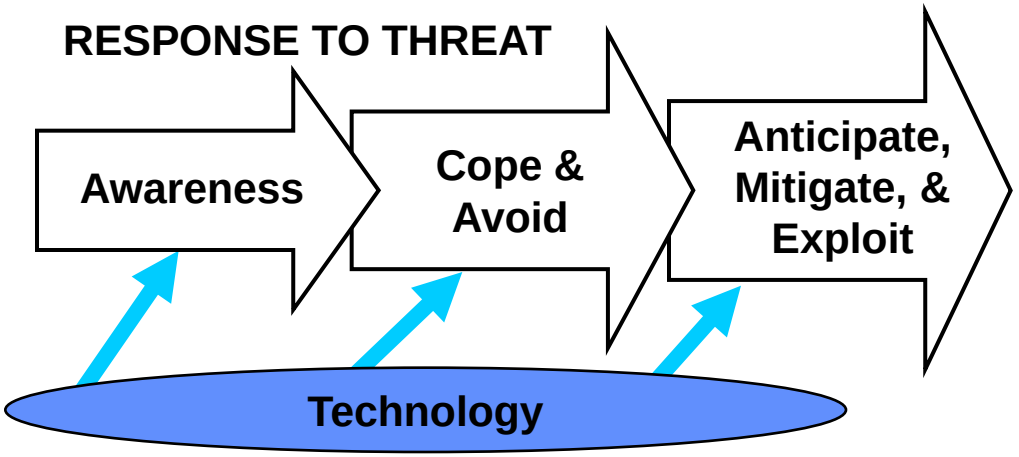
Space Environmental Monitoring & Effects Impacts

The natural space environment affects military operations because warfighters depend on space-based assets to execute combat missions

- Single event upsets (SEUs) due to high energy particles
- Satellite position errors due to changes in atmospheric density
- Comm/nav capability degraded or lost because of ionospheric anomalies
- Radar false target identification due to ionospheric anomalies
- Long-term degradation of spacecraft due to environment
- Optical & RF anomalies due to solar emission
- Discrimination between natural & man-made effects on spacecraft

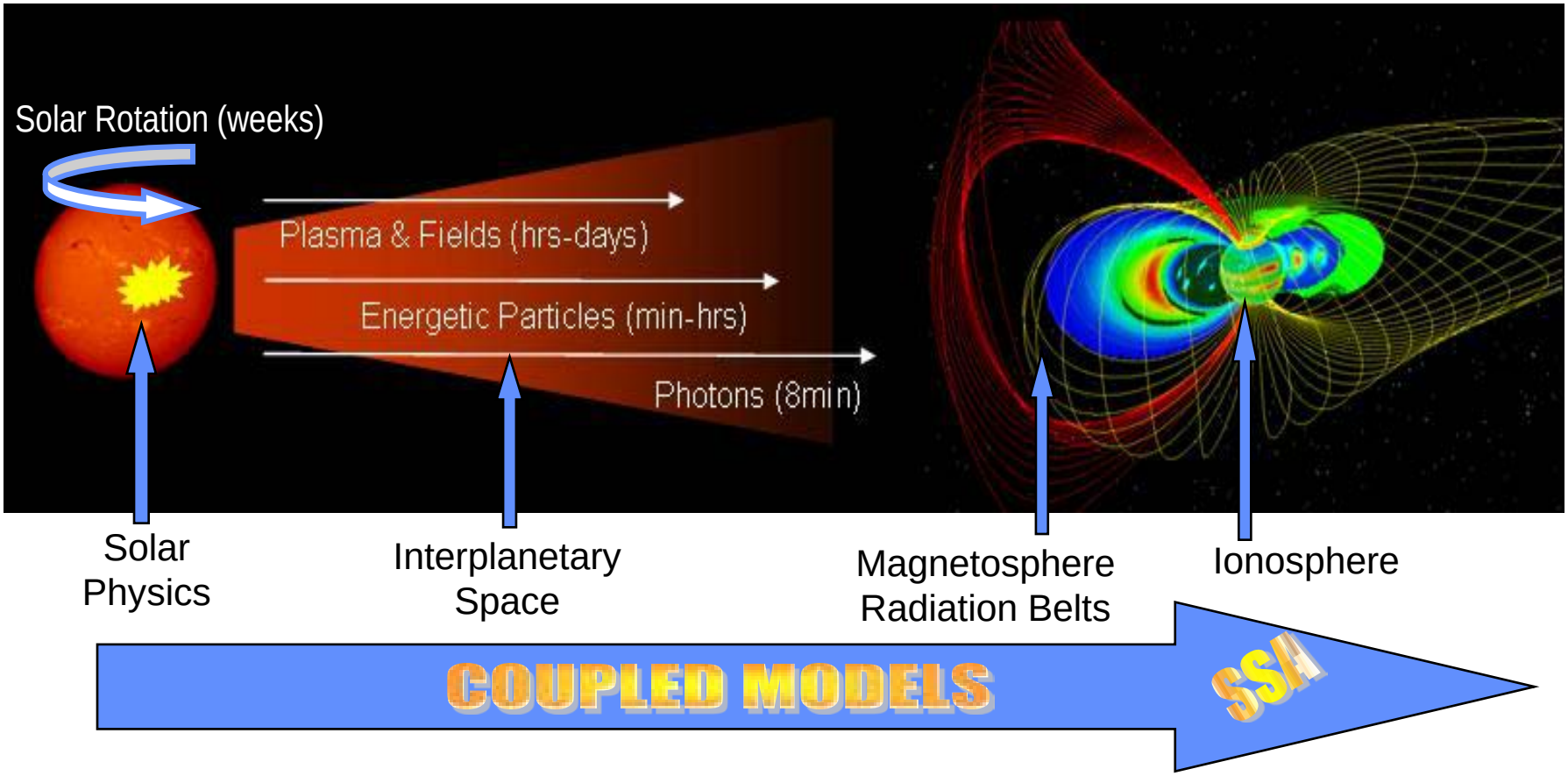






72 Hour Forecasting

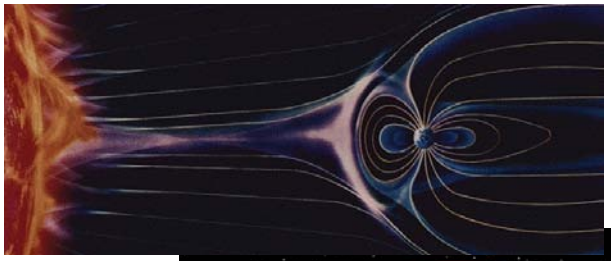
Space weather effects propagate from the Sun on a wide range of time scales

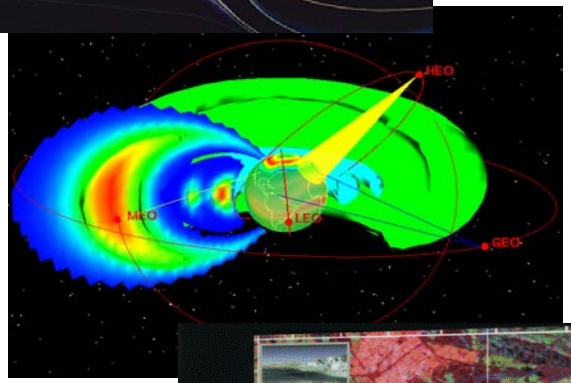


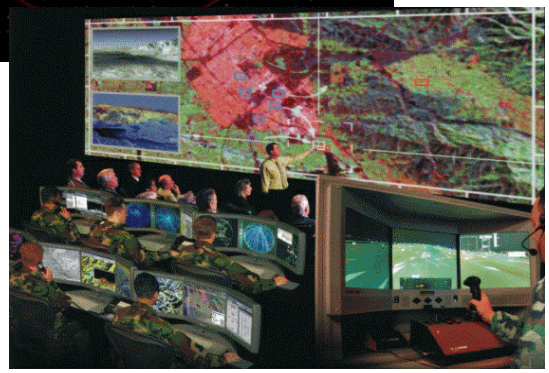
Challenging 72 hr requirement comes from “Air Tasking Order”

Soon to be 120 hr

Space Environmental Monitoring & Effects Development Vector





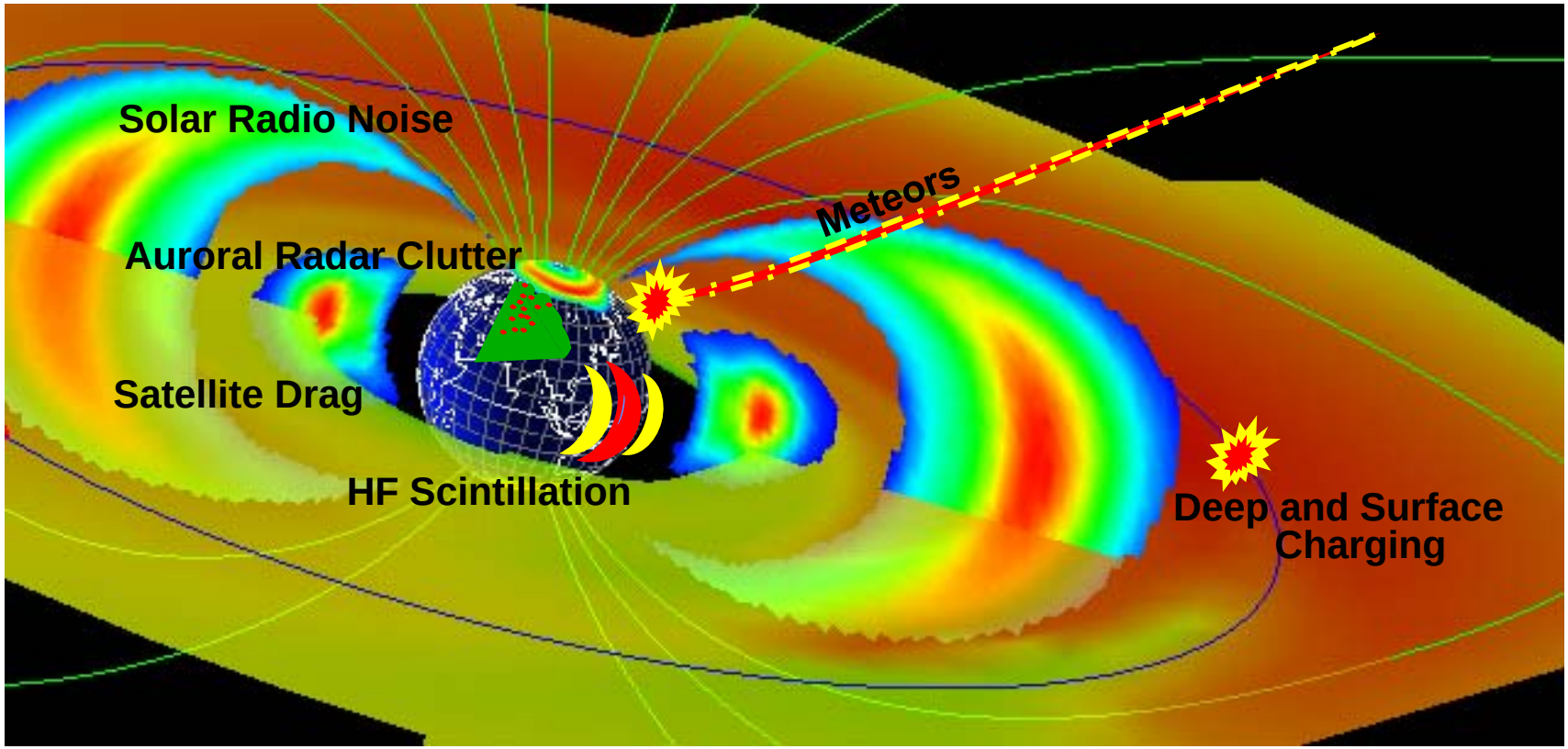


- Advance the national (and world) ability to **measure** and monitor the space environment from ground-based and spaced-based assets (NSSA, SEEMS)
- Develop physics-based and assimilative **models** and applications (CISM, GAIM, SEEFS, SWAFS)
- Develop **mitigation** technologies and decision quality impact forecasts for Combatant Commander's Single Integrated Space Picture (SISP, SEEFS)

Goal: Advance capability from specification of the space environment to long term forecasting of effects

SEEFS, the Space Situational Awareness Environmental Effects Fusion System

SEEFS is a comprehensive tightly coupled system of specification, forecast, and effects models tailored to provide asset specific forecasts of operational SWx impacts

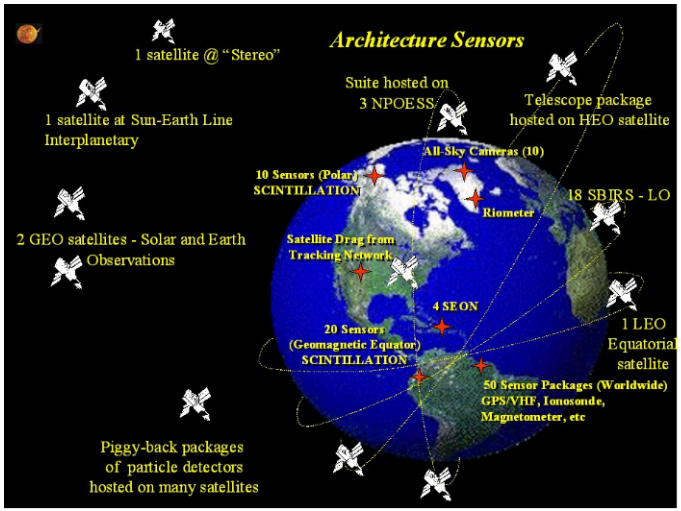


SEEFS is a SMC led effort, executed by AFRL

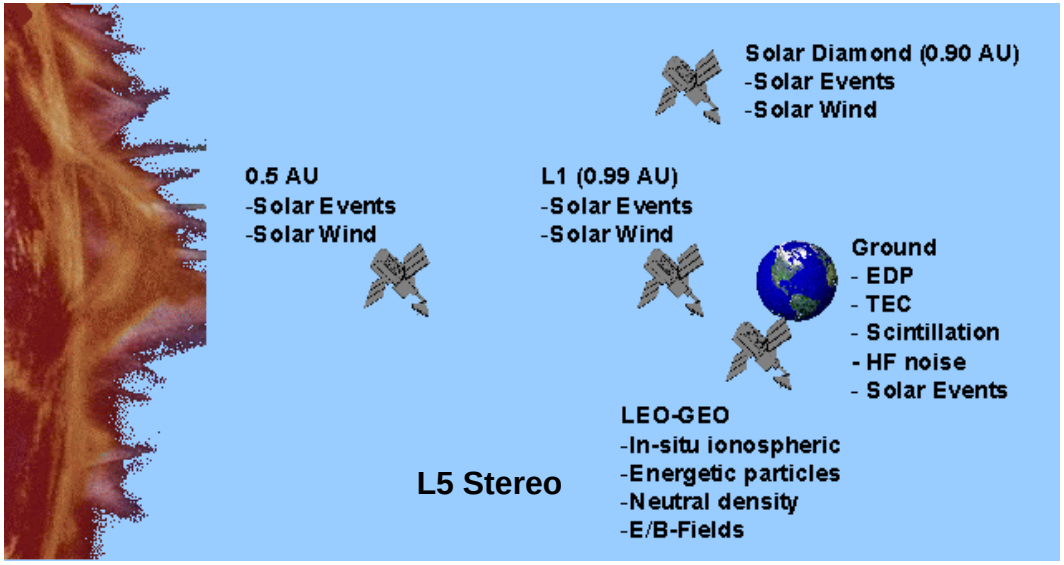
SEEMS Concept Overview

Space Environmental Effects Monitoring System

- Space- and ground-based sensors required to provide AF with specification and forecast of the space environment and effects on military systems
- Thermosphere to the surface of the sun
- Includes impacts e.g., radio frequency propagation (UHF SATCOM, GPS PNT, radar) and spacecraft (charging, SEE, radiation dose, satellite drag)
- Based on National Security Space Architecture (1999) and the Space Weather Architecture Plan (2000)
- Intended as implementation plan for DoD components, i.e. **Leadership**



NSSA, 1999



SEEMS

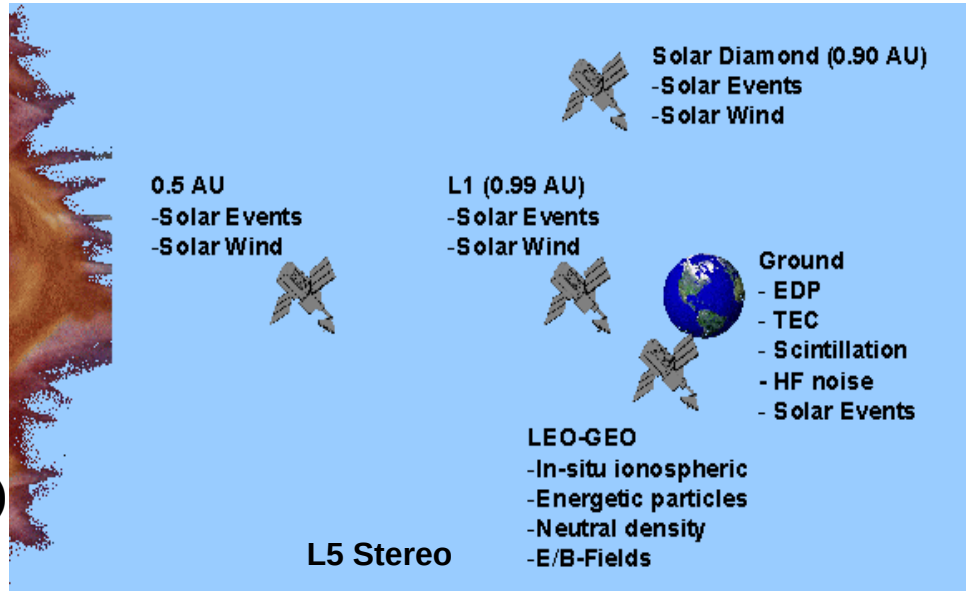
SEEMS Concept Overview

SEEMS is Sensors, Orbits and Satellites

- Models and products are covered in the SSA Environments Effects Fusion System (SEEFS) concept
- SEEFS details are not needed to specify EM architecture
  - Physics understanding is adequate to choose and place sensors
  - Impact of modern assimilative models is implicit and important
- Three spirals provide sequentially longer and/or better forecasts up to 72 (120) hrs

Sensor groups

- Ground based sensors
  - Solar, ionosphere, thermosphere
- Equatorial and Polar SWx LEO sats
- MEO-GEO sensors, rides of opportunity
- SolGuard: near-Earth solar and solar wind sats
  - L1 (0.99 AU, solar, P&F)
  - Space Weather Diamond (0.9 AU, P&F)
  - L5 Stereo (solar, P&F)
- Solar Sentry: solar wind at 0.5 AU
  - P&F compliment to NASA Sentinels



SEEMS

Background and Motivation

The current method of acquiring operational space weather systems is too cumbersome and expensive to allow AF to take a leadership role in building a SWx architecture

- **Cost is driven by operational requirements, not all of which pertain to the space environment**
- **Currently, the value of each piece is based more on the utility of data to the immediate customer base of scientists & forecasters, and less on the utility to operators or warfighters**
- **Full value is realized only after assimilation into models with data from many other sources, and forecast products delivered to end users**
- **If adequate data for the products must wait on ponderous acquisitions, SWx sensing platforms will always score low and nothing is ever built**

Boost value by costing the entire architecture using an appropriate acquisition paradigm

Requirement Satisfaction

SEEMS satisfaction of AFSPC 06 SFE MAP requirements

- **Requirements are based the requirement to simply specify certain aspects of the current state of the ionosphere**
- **EM capability prescribed by these requirements does not support forecasting for Space Superiority**

Need Number & Name	Current AFSPC 06 Assessment	Spiral 1 (includes current assets)	Spiral 2	Spiral 3
3.3.2.1 Upper Atmosphere	Y	Y	G	G
3.3.2.2 Ionosphere	Y	G	G	G
3.3.2.3 Magnetosphere	Y	Y	G	G
3.3.2.4.1 Background Solar Wind	G	G	G	G
3.3.2.4.2 Solar Eruptive Events	G	G	G	G
3.3.2.4.3 Solar EM Spectra	G	G	G	G

Yellow/medium (34-67%), green/high (68-100%)

Requirement Satisfaction

AFSPC Functional Concept for Space Superiority Operations

- **AFSPCSSCC 1.1.6.7.1: Assess and forecast natural space environmental events and the impacts**
- **EM community interpretation of 72 hr forecast requirement**
- **EM-TPIPT interpretation of SEEFS needs**

Environmental domain or phenomena	Current Capabilities	Spiral 1 (includes current assets)	Spiral 2	Spiral 3
Upper Atmosphere	R	Y	G	G
Ionosphere	Y	Y	Y	G
Magnetosphere	R	R	Y	G
Background Solar Wind	Y	Y	Y	G
Solar Eruptive Events	Y	Y	G	G
Solar EM Spectra	G	G	G	G

Yellow/medium (34-67%), green/high (68-100%)

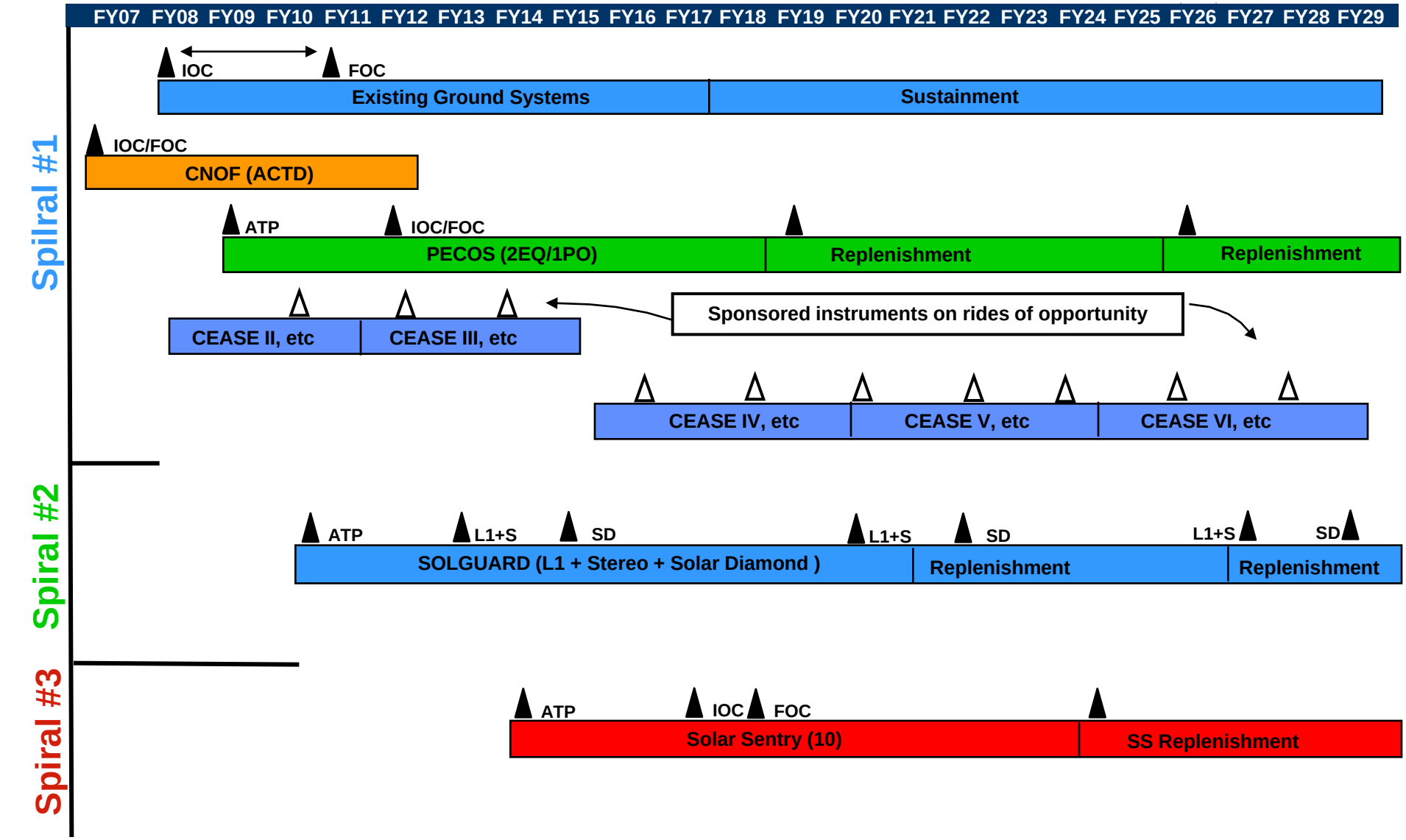
SEEMS Functional Breakdown

SEEMS is broken into 2 functional areas

- **SEEMS-RF: specify and forecast impacts on RF based systems**
- **SEEMS-SC: specify and forecast impacts on Space assets**
- **SEEFS is not included in SEEMS breakdown, but does play a critical role in turning data into products**

		SEEMS	
		SEEMS-RF (Radar, Comm, PNT, EO ISR)	**SEEMS-SC** (S/C charging, HRE, SEE, dose, drag)
Nowcast	*data*	TEC, scintillation, EDP, in situ plasma, solar RF obs, HF Noise	GEO-MEO-LEO particle flux & spectra (KeV-MeV), sat tracking, F10.7(drag)
	ground support	15 min latency	15 min latency
	models	Assimilative, climatological	Assimilative, climatological
Short-Term Forecast	*data*	E-field, neutral wind	L1 solar wind pressure & mag field
	ground support	30 min latency	30 min latency
	models	Climatological, physics-based	Climatological, physics-based
Mid-Term Forecast	*data*	Magnetosphere, solar wind, IMF	0.9 AU solar wind obs, CME tracking
	ground support	60 min latency	60 min latency
	models	Physics-based, coupled	Physics-based, coupled
Long-Term Forecast	*data*	0.5 AU solar eruptive obs, CME imaging & tracking	
	ground support	60 min latency	
	models	Coupled	

SEEMS Roadmap



SEEMS Spiral #1

- **Staged by cost, TRL, and progression from Nowcast to Forecast**
- **Cost: < 2B$**

SYSTEM	Description	ORBIT	IOC
Spiral 1			
Next Gen Ionosonde	Automated Iono Profile	na	FY07
TEC Stations	TEC from AF and non-AF stations	na	FY06
SCINDA	RF effects, Ionospheric turbulence	na	FY07
SRBL	Solar Radio Bursts		
ISOON	Solar Activite Regions	na	
C/NOFS Resid Ops	Iono In Situ (Neu & Ion Den & Wind, E&B, GPS Occult, RF Beacons)	LEO	FY06
PECOS	Operational C/NOFS	(1) Eq. and (2)Polar	FY14
CEASE	Hosted SWx sensors	MEO and GEO	FY06

SEEMS does not include the models, but they play a key role in enabling data assimilation, forecasting, and effects prediction

The models need SEEMS

SEEFS	Sys Impacts, Ground to GEO	FY10
GAIM	Iono assimilation	FY08
TBD	Global assimilation	FY 12

SEEMS Spiral #2

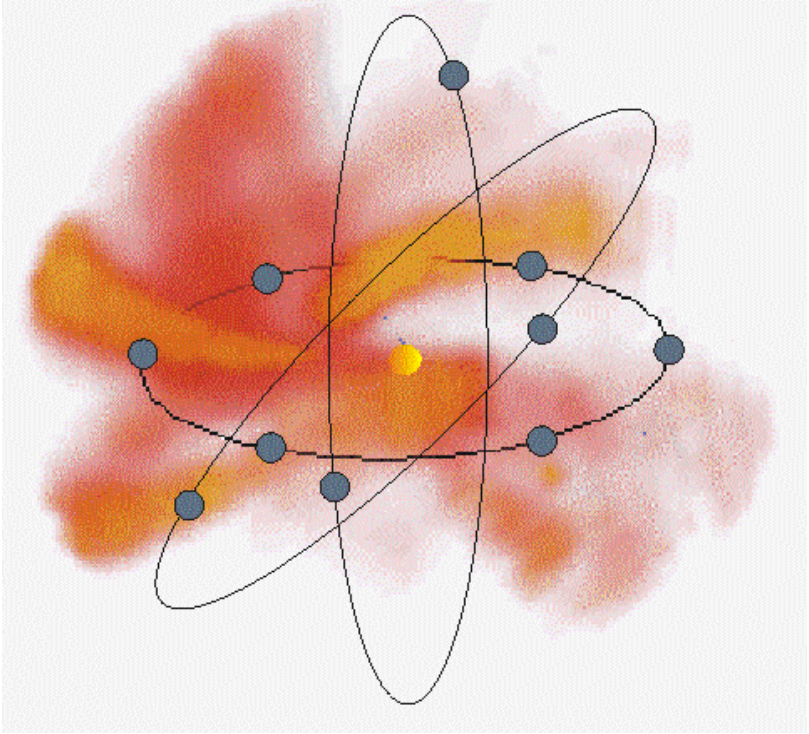
- **Provide a comprehensive Solar and Solar Wind data stream to enable accurate and predictive models**
  - **4 to 12 hr forecasting of impending Solar Wind conditions**
  - **Stereo coronal observations enable multi-day forecasts of likely Solar Wind and RF conditions**
- **Cost: < 3.5B$ including replentishment**

SPIRAL 2			
SYSTEM	**Description**	**ORBIT**	**IOC**
SolGuard	Coronal observation, CME & Solar Wind	L1 + Stereo(1)	FY14
SolGuard	CME + Solar Wind	0.9 AU Space Diamond (4)	FY14

- **Space Weather Diamond. Four satellites in 1.1 x 0.9 AU eccentric orbits effectively circling the Earth (O.C.St.Cyr et.al., JASTP, V62.No14, 2000)**

SEEMS Spiral #3

- Spiral 3 = Solar Sentry (~= Solar Sentinels, NASA)
- 10 DoD micro-satellites plus 4 NASA satellites in 0.4 to 0.6 AU Solar orbits
- Optimal upstream in situ Solar Wind observation
- Shared satellite bus and payload with SolGuard spacecraft
- Particle and Field sensors only
- Cost: < 3 B$ for 10 sats and replentisment
- Partnership with NASA, NOAA, and foreign programs will extend coverage and reduce costs



Acquisition Plan/Philosophy

The space environment is a highly coupled system where a forecast for one region often requires data from all over the earth-solar space

- Assimilative models are adaptive to the add/loss of any one data set
- In most cases, warfighters do not directly use satellite environmental data but depend on model assessments and decision aids
- Thus, the effectiveness of these new assimilative models is limited more by data quantity than by data quality (degree of reliability)

SEEMS must be a Responsive Space Weather Program with a dedicated program office with the authority and budget to build SEEMS

- Single SPO for multiple and dissimilar missions
- Baselined on mature technology, tech infusion only as ready
- Trade data assurance and associated costs for increased quantity of data
- Operational use of prototype and research class assets, e.g. ACE, SOHO, C/NOFS
- Responsive partnering e.g. STEREO, SWARM

The proposed acquisition concept will enable the AF and DoD to take a leadership role in achieving an effective space weather architecture

AFRL Programs in SWx
8. 72 Hour Forecasts