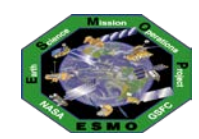


ESMO's Approach to CARA Devolution

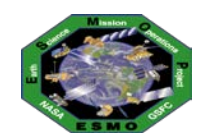
Dimitrios Mantziaras, Terra Mission Director
June 12-14, 2018



ESMO RMM Planning Automation



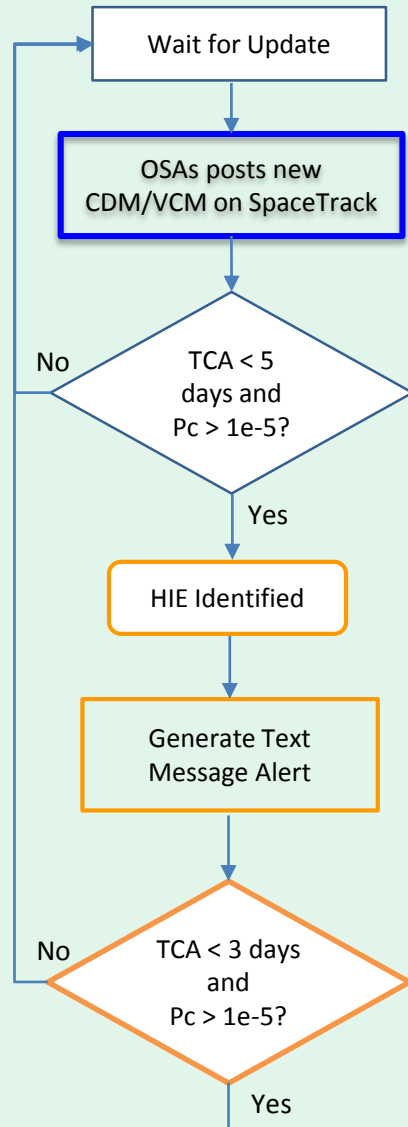
- **ESMO has updated its Close Approach (CA) Process Flow to a more Automated approach**
 - Prepares for future increased object catalog w/ Space Fence
 - Reduces workload for each event
 - Keeps solution “at the ready” for short notice events
- **ESMO Flight Dynamics team has developed an autonomous Ephem Generation Tool**
- **Ephems built off optimal and constrained cases solved for by the Collision Risk Management System (CRMS)**
- **CARA accepts delivery of these ephems and ships them to JSpOC for screening**
 - Delivery to CARA is now automatic based on logic built into the FDS ephem tool to whittle ephems down from maximum of eight generated to a maximum of five delivered
 - Any other options needed can be sent manually
- **Screening results automatically compiled and outputted via an email report from CRMS**
- **Auto Ephem Generation implemented in February 2017**
- **Auto Ephem Delivery implemented in February 2018**
- **CARA Devolution Working Group created – biweekly meetings begun on 5/16**
 - Goal is to identify gaps between ESMO current capability and traditional CARA support
 - Work done to close gaps will be tracked to completion via this Working Group



ESMO's Automated CA Process Flow (Updated June 2016)

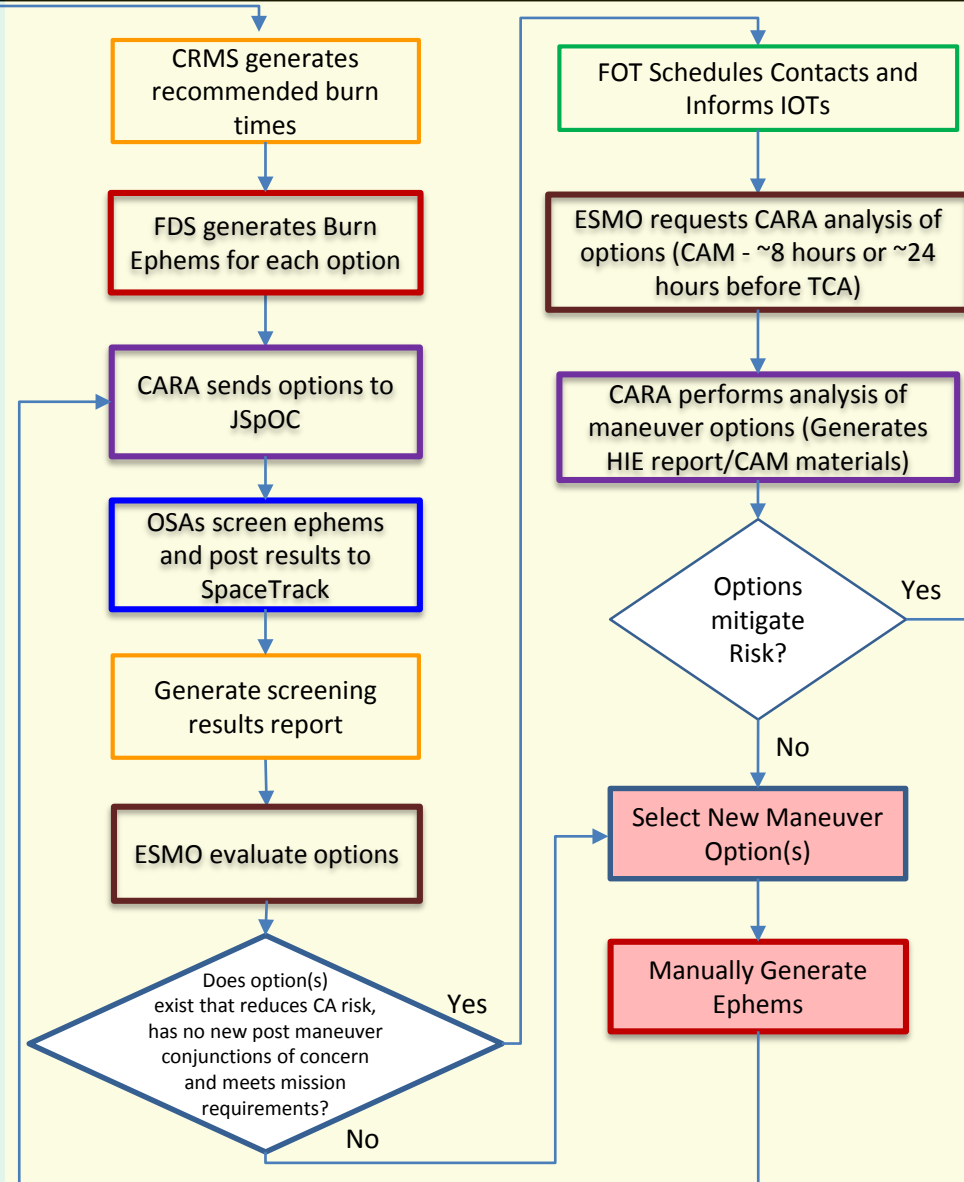


Identification



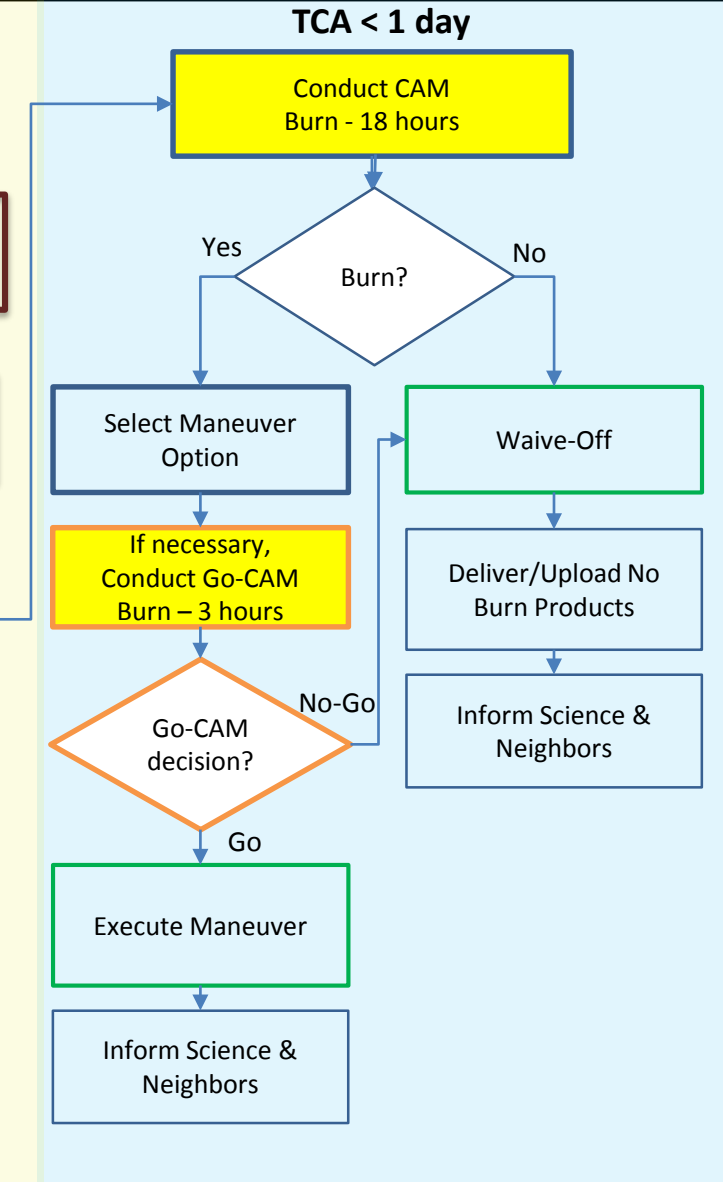
Summary Report

Planning

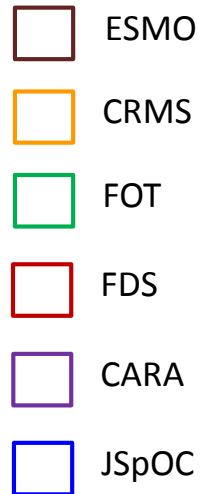


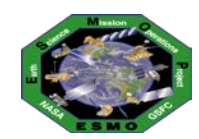
CRMS Maneuver Report

Execution



CRMS Maneuver/HIE Report

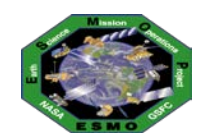




EOS Maneuver Thresholds for DAM/No-DAM

	Pc Thresholds	Odds Range	Course of Action	Sample Scenarios
Green	$<1.0e^{-5}$	1:100,000 to 0	No DAM	
Yellow	$(1.0e^{-4}-1.0e^{-5})$	1:10,000 to 1:100,000	Altered DMU/No DAM	Replan Nominal DMU burn time or execute DMU early <u>if available</u> For well-tracked objects with small miss distances
Orange	$(1.0e^{-3}-1.0e^{-4})$	1:1,000 to 1:10,000	DAM	Solution <u>within</u> mission/science requirements and low uncertainties
Red	$(1.0e^{-2}-1.0e^{-3})$	1:100 to 1:1,000	DAM	Execute even if <u>outside</u> mission/science requirements
Black	$\geq 1.0e^{-2}$	1:1 to 1:100	DAM	Maneuver at all costs Even if Ongoing Anomaly (Non-Maneuver Component)

- All unacceptable risks are mitigated
- Additional risks are mitigated within mission/science constraints
- Confidence in OD solution/risk accuracy must be considered as well



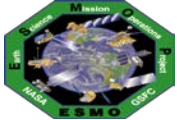
Operational CA Requirements



Function	CARA/OSA	CRMS/SpaceNav
Gather CDM/VCM data from JSpOC	✓	✓
Compute Probability of Collision	✓	✓
Process O/O information (mission ephem)	✓	✓
Generate Maneuver Trade Space Plot	✓	✓
Provide Summary Reports after each JSpOC screening update	✓	✓
Provide Full Secondary Information for High Risk Conjunctions	✓	✓
Provide Future Sensor Tracking Opportunities	✓	✓ Capability exists
Assess OD quality for each secondary and refine if needed	✓	✓ Capability exists
Update tasking for objects as required	✓	✓
Provide mitigation strategy for High Interest Events	✓	✓
Deliver Ephems to JSpOC for screening	✓	✓ Capability exists
Process screening results	✓	✓



Capability already exists on CRMS just not currently utilized for ESMO



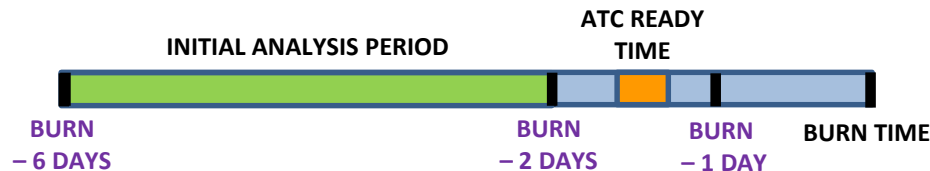
ESMO CA Process

- Black text = Manual
- Blue text = Automated



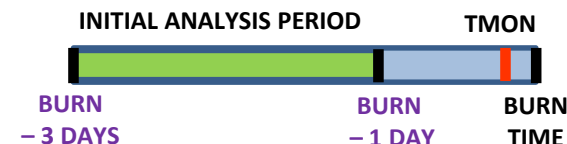
Historical Process

- Identify High Interest Event (HIE) via visual inspection of Summary Report
- Call HIE Briefing Meeting to gather details of conjunction
 - CARA prepares/presents HIE slides
- Hold more briefs and exchange emails to gather additional data until TCA
- Pick mitigation solutions from selecting points off a Maneuver Trade Space Plot
- FOT schedules additional contacts
- FDS generates ephems for each maneuver solution (~ 1 hr per ephem)
- FDS transfers ephems to CARA
- CARA transfers ephems to JSpOC for screening
- JSpOC transfers screening results back to CARA
- CARA generates screening results report and briefs interested parties
- MD/Team selects or iterates on final solution
- Hold CAM
- Execute DAM/RMM or Waive-Off
 - Maneuver ATC based with manual instrument configurations (1-2 days needed prior to maneuver)

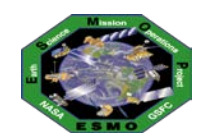


Current Process (December 2017)

- Identify High Interest Event (HIE) via CRMS
 - Text message sent by CRMS
 - CRMS Summary Report is available if a Mission Director wants to review a series of conjunctions at one time.
- CRMS produces maneuver report with all conjunction details and mitigation options
- CRMS produces new report everytime new data is received and recomputes mitigation solutions
- FOT schedules additional contacts
- FDS generates ephems for each maneuver solution automatically based on output from CRMS
- FDS automatically transfers ephems to CARA
- CARA transfers ephems to JSpOC for screening
- JSpOC transfers screening results back to CARA
 - Direct JSpOC Space-Track interface was demonstrated in November
- CRMS generates screening results report automatically based on CDMs posted to SpaceTrack
- MD/Team selects or iterates on final solution
- Hold Command Authorization Meeting (CAM)
- Execute DAM/RMM or Waive-Off
 - Maneuver TMON/RTCS based (2 hours lead time needed)



Typically schedule burn between 2 ½ to ½ orbits before TCA

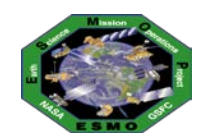


Changes Needed for ESMO



Devolution Working Group created to address updates needed:

- 1. Develop direct communication path to JSpOC/OSAs**
 - Communication path from O/O to O/O
 - Communication path for classified secondary
- 2. Finalize direct ephemeris delivery path through Space-Track**
 - Successfully performed test in December with [JSpOC crew](#) (1 week)
 - Successfully performed second test (4/30 – 5/11) with [Goddard OSAs](#) (2 weeks)
 - ****NOTE**** - Deliver of ephemeris through SpaceTrack preserves ephemeris name
- 3. Update ephemeris naming to JSpOC convention (FDS & CRMS)**
- 4. Update documentation to reflect change**
 - Operations Concept Document
 - Memorandum of Understanding
 - Implementation Plan
- 5. Setup reporting paths and templates**



ESMO Lessons Learned



- **Commercial Provider allows for a customized solution to meet mission specific needs**
 - Predetermined and preformatted data on demand
 - Customized maneuver solutions to meet unique mission constraints (WRS, geodetic height, etc)
 - Mission can define their own maneuver thresholds
 - Greater flexibility for automation of maneuver planning
 - Allows for integration with existing mission automation locally
- **Commercial providers can use existing standard interface with JSpOC**
 - Leverages existing work already done and supported by the JSpOC
- **Renaming of ephemeris has caused confusion in the past**
 - CARA created CDMs to address renaming issue
 - To use CARA generated CDMs, commercial provider need to create new code unique for NASA missions which is not required when using standard JSpOC CDMs.
 - Issue also solved by using Space-Track as ephem delivery mechanism
- **ESMO's use of commercial CA services has reduced the need for CARA Operations**
 - Currently CARA is performing a sanity check of the commercial services solutions
- **ESMO has not identified service loss by using commercial provider**
 - Has provided more control and greater flexibility



Example Summary Report



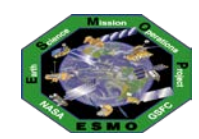
EOC Open ESMO Conjunction Event Data **EOC Open**

For raw CDM data: [Space-Track](#)

	Spacecraft	Combined HBR [m]	Primary Object Ephem Source	Total # Unique Active Events	# of Unique Events Updated in the Delivery	Total # Unique Events Pc > 1.0E-5	Total # CDMs Processed in last download	Last Data Download Time	Aggregate Pc	Total # State CDMs
	AQUA (27424)	20	ASW	17	17	0	17	2018-05-16 15:41:00	5.52e-14	9
			S01	17	17	0	17	2018-05-16 15:41:00	5.02e-14	0
	AURA (28376)	20	ASW	7	7	0	7	2018-05-16 15:41:00	2.11e-15	12
			S01	6	6	0	6	2018-05-16 15:41:00	1.78e-15	0
	GPM (39574)	8	ASW	8	8	0	8	2018-05-16 15:41:00	0.00e+00	0
			S02	6	6	0	6	2018-05-16 15:41:00	0.00e+00	0
	TERRA (25994)	20	ASW	11	11	0	11	2018-05-16 15:41:00	4.05e-09	10
			S01	9	9	0	9	2018-05-16 15:41:00	0.00e+00	0

Note about data used in the table above: Calculations where the primary object ephem sources are A SW include all active unique events with non-state data (this is also true for the Owner/Operator total number of state CDMs count). Calculations where the primary object ephem sources are Owner/Operator only include data processed in the last download (so Owner/Operator data will only appear in this table if it appears in the table below).

* Event Flags: SNO (Secondary New Observation Flag), SNS (Secondary New Solution Flag), RV (Low Relative Velocity), M (Low Miss Distance), PST (Primary - State Tracking), SST (Secondary - State Tracking), PE (Primary - High EDR), SE (Secondary - High EDR), POS (Primary - OD Span Flag), SOS (Secondary - OD Span Flag), PLO (Primary - Low Observations), SLO (Secondary - Low Observations), PW (Primary - High WRM S), SW (Secondary - High WRM S)													
Report Gen Time to TCA [Days]	Primary Object & RJC Uncertainties [m]	Secondary Object & RJC Uncertainties [m]	Primary Object Ephem Name	Screening Epoch	TCA [UTC]	Total Miss [m]	Radial Miss & (Uncertainty) [m]	In-Track Miss & (Uncertainty) [m]	Cross-Track Miss & (Uncertainty) [m]	Approach Angle [deg]	Collision Probability	Tracking Latency - Secondary Object	Event Flags *
0.7	AQUA (27424) [2 / 27 / 3]	FENGYUN 1C DEB (32409) [43 / 582 / 70]	AQUA_20180516_MJ2K.27424.93831.S01	2018-05-16 14:36:27	2018-05-17 06:25:15	20013	12 (43.0)	3093 (375.3)	-15773 (107.1)	162.3	0.00e+00	35 hours 2018-05-15 03:20:35	SLO SW
0.7	AQUA (27424) [1 / 14 / 1]	FENGYUN 1C DEB (32409) [43 / 582 / 70]	A SW	2018-05-16 14:36:29	2018-05-17 06:25:15	20005	15 (43.0)	3089 (374.5)	-15765 (107.0)	162.3	0.00e+00	35 hours 2018-05-15 03:20:35	SLO SW



Example Maneuver Trade Space Plot



Maneuver Planning Results

