Mission Operations Cost Estimation Tool (MOCET) 2022 Research

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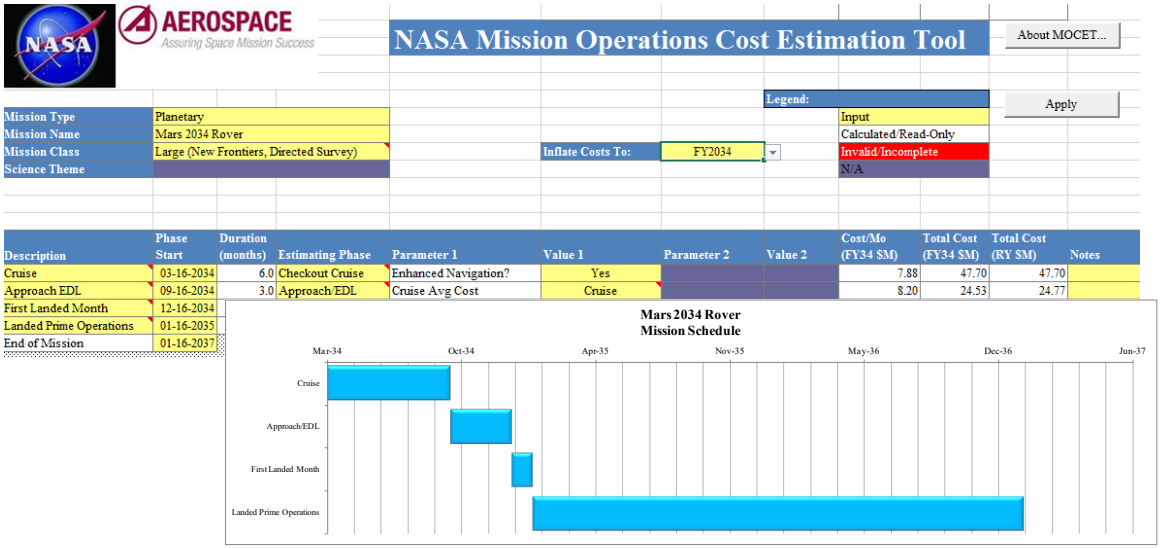
Topics

- MOCET Overview
- Mission Data Updates
- Extended Missions Investigation
- Level 2 WBS Investigation
- User Community
- Conclusion

MOCET Overview

- The Mission Operations Cost Estimation Tool (MOCET)
  - *A capability for Phase E estimation jointly developed by The Aerospace Corporation and NASA Science Office for Mission Assessments (SOMA)*
  - *Based on actual costs of historical missions with emphasis on competed missions*
  - *Constructed by breaking the mission operations cost into the various phases*
  - *Has few subjective inputs*
  - *Estimates total Phase E mission cost*
  - *Implemented entirely in Excel and requires no additional software or tools*
  - *Also includes a user manual which provides additional instruction and background*



Download from ONCE Model Portal
https://oncedata.hq.nasa.gov

Available external to NASA via
https://software.nasa.gov

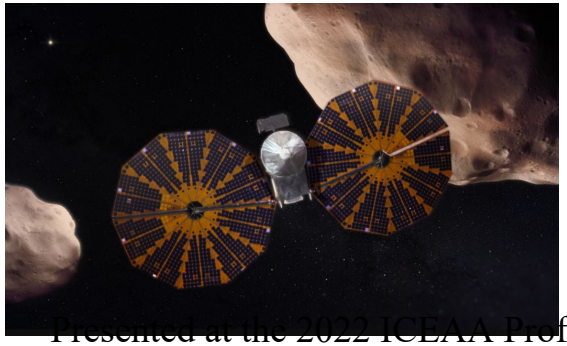
For more information:
Email: MOCET@aero.org

Mission Data Updates

Mission/CER Type	Program	Missions
Planetary	Discovery	MESSENGER, Stardust, Deep Impact, GRAIL, NEAR, Dawn, **Lucy**
	Mars Scout	Phoenix
	Robotic Lunar Exploration	LRO, LADEE
	New Frontiers	New Horizons, Juno**, OSIRIS-REx**
	Mars Exploration	MRO, Odyssey, MER, MSL, MAVEN**, Insight, Mars 2020**
	Planetary Defense	**DART**
Earth Science	Earth System Science Pathfinder (ESSP)	GRACE, CloudSat, CALIPSO, Aquarius, OCO-2, **CYGNSS, OCO-3, GEDI**
	Earth Systematic Missions (ESM)	Aqua, Aura, Terra, Jason-1, OSTM, ICESat, GPM, **SMAP, TSIS-1, ICESat-2, GRACE-FO, Sentinel-6 Michael Freilich**
Explorers	Mission of Opportunity (MO)	Suazku (ASTRO-E2), TWINS, CINDI, **NICER, GOLD**
	Small Explorers (SMEX)	NuSTAR, IRIS, IBEX, AIM, GALEX, RHESSI
	Medium Explorers (MIDEX)	THEMIS, Swift, WISE, **TESS, ICON**
Near Earth Discovery Helio-Astro	Discovery	Genesis, Kepler
	Solar Terrestrial Probes (STP)	STEREO, TIMED, MMS
	Living With a Star (LWS)	RBSP, SDO, **PSP**
	Cosmic Origins	Spitzer
	Physics of the Cosmos	Fermi, Chandra

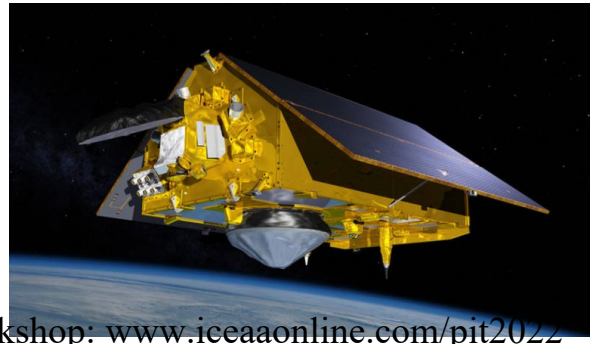
Bold = New Data in 2021

Potential New Data for possible 2022 update



Lucy

DART



Sentinel-6 Michael Freilich

Extended Mission Investigation

Database

- All data obtained from the NASA Systems, Applications & Products (SAP) Business Warehouse
- Includes 39 missions
- 4 mission categories
  - *Explorers*
  - *Earth Science*
  - *Other Helio & Astro*
  - *Planetary*
- Further categorized by science theme and mission class

Mission Category	Science Theme	Mission Class	Mission	Launch Date	Prime Mission End
Explorers	Heliophysics	SMEX	AIM	4/25/2007	6/1/2009
			IBEX	10/19/2008	10/19/2010
			RHESSI	2/5/2002	2/5/2004
		MIDEX	THEMIS	2/17/2007	9/30/2009
			IRIS	6/27/2013	7/26/2015
		MO	TWINS	3/13/2008	5/20/2010
			CINDI	4/16/2008	4/16/2010
	Astrophysics	SMEX	NuSTAR	6/13/2012	6/13/2014
			GALEX	4/28/2003	8/25/2005
		MIDEX	Swift	11/20/2004	1/21/2007
			Fuse	6/24/1999	10/15/2007
		MO	Suzaku	7/10/2005	9/30/2010
Earth Science		Small	SORCE	1/25/2003	1/1/2008
			GRACE	3/17/2002	3/1/2007
			Jason-1	12/7/2001	12/7/2004
		Medium	CloudSat	4/28/2006	3/10/2008
			CALIPSO	4/28/2006	4/28/2009
			ICESat	1/13/2003	4/12/2006
		Large	GPM	2/28/2014	5/29/2017
		Flagship	Aqua	5/4/2002	6/1/2008
			Aura	7/15/2004	9/30/2010
			Terra	12/18/1999	3/18/2005
Other	Heliophysics	Medium	TIMED	12/7/2001	12/7/2003
		Large	MMS	3/12/2015	9/1/2017
			SDO	2/11/2010	2/11/2015
			Van Allen Probes (RBSP)	8/30/2012	11/30/2014
			STEREO	10/26/2006	10/25/2008
	Astrophysics	Large	Kepler	3/7/2009	11/12/2012
			Fermi	6/11/2008	8/28/2013
		Flagship	Spizter	8/25/2003	5/25/2006
Planetary	Orbital	Medium	Dawn	9/27/2007	6/30/2016
			MESSENGER	8/3/2004	3/17/2012
			MAVEN	11/18/2013	11/14/2015
			Mars Odyssey	4/7/2001	8/24/2004
			MGS	11/17/1996	1/31/2001
		Large	MRO	8/12/2005	10/1/2008
		Flagship	Cassini	10/15/1997	7/1/2008
	Landed	Large	MER	6/10/2003	4/26/2004
				7/7/2003	
		Flagship	MSL	11/26/2011	9/29/2014

Extended Mission Investigation

Observations & Approach

- Overall trend of extended mission costs is that they decrease over time, likely due to:
  - *Efficiencies developed throughout continuous operations*
  - *Prime operations may be broader & extended operations become more focused*
  - *Capability of system becomes limited over time due to aging technology*
  - *Personnel transition to newer missions over the extended mission lifetime*

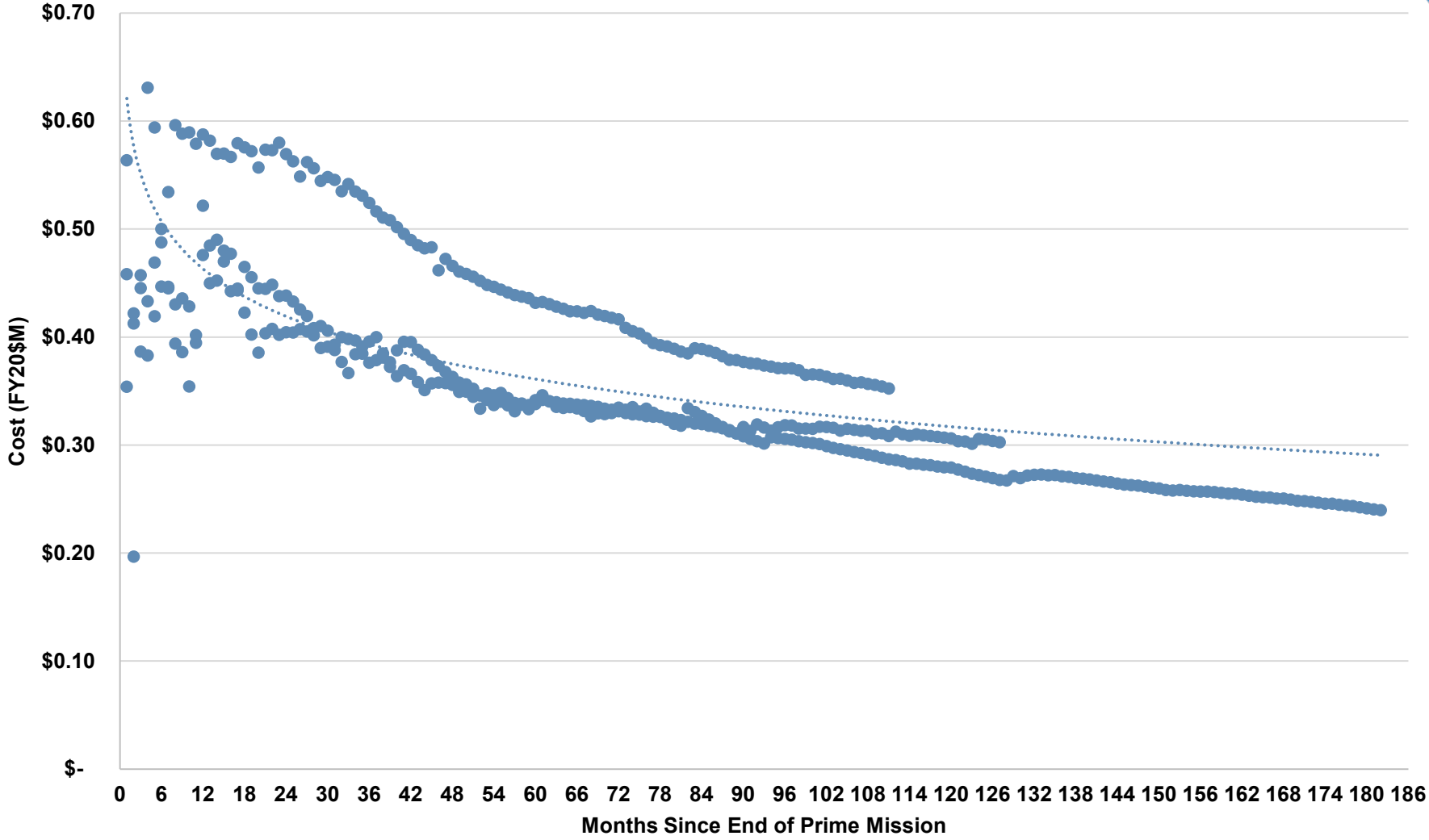
- Attempted to combine and model mission together by category
  - *Different levels and combinations attempted*

- Examined numerous modeling techniques including:
  - *Cumulative average cost*
  - *12-month moving average cost*

- Developed initial models using 12-month moving average
  - *Models are still being refined further*

Extended Mission Investigation

Example Graph of SMEX Heliophysics Data



Cumulative average clearly demonstrates diminishing trend as it becomes smooth line

Requires monthly cost for entire extended mission starting from end of prime mission

Extended Mission Investigation

Example Graph of SMEX Heliophysics Data

12-month moving average data has more variability, but still shows diminishing trend

Average cost at any point in time better demonstrates actual monthly rate vs. cumulative

Extended Mission Investigation

Next Steps

- Continue to refine CERs for extended mission costing
  - *Investigate and normalize out of family data*
  - *Collect additional accumulated data*
  - *Explore incorporating additional variables where possible*

- Explore starting the mission monthly clock at the start of the prime mission

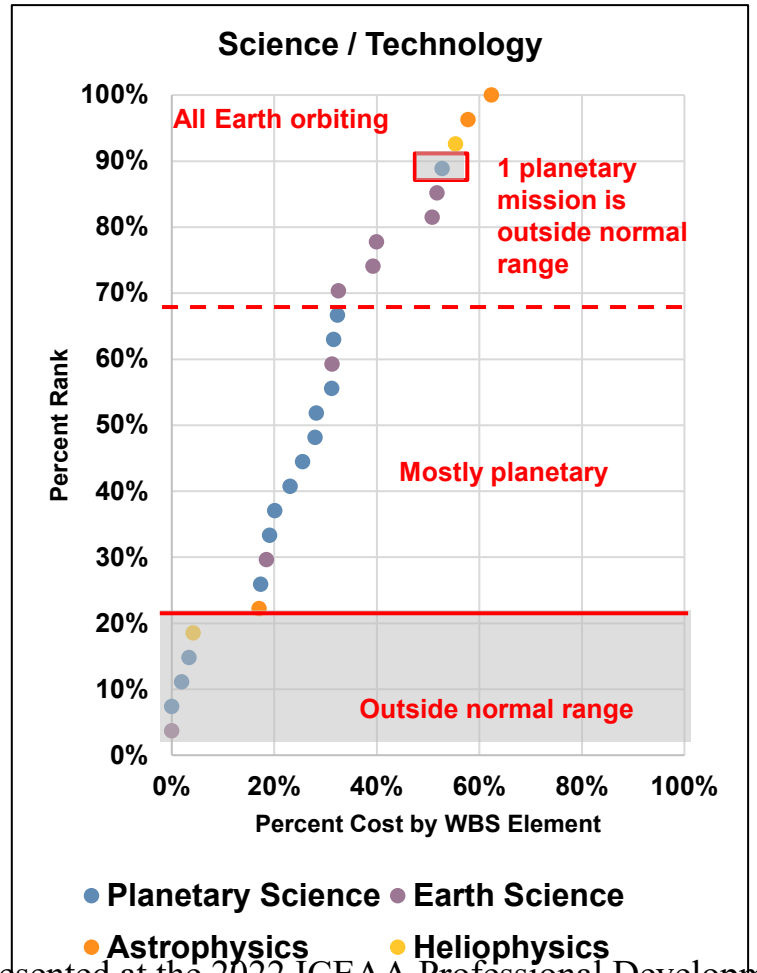
Level 2 WBS Investigation

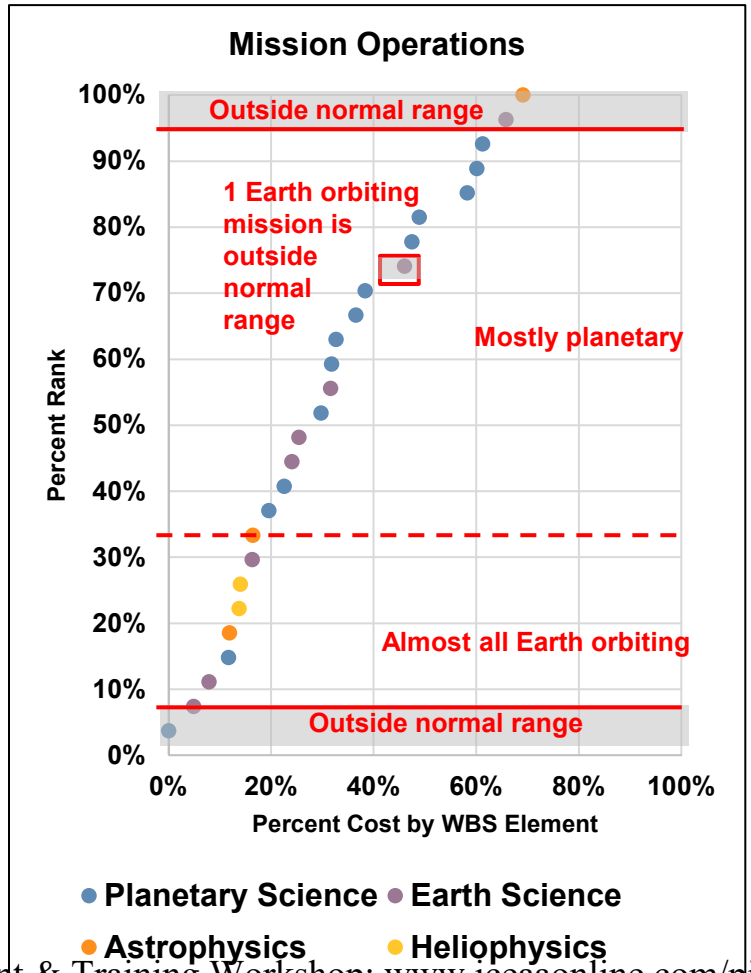
- Level 2 WBS Modeling investigation performed in 2021 and continuing in 2022
- 2021 study included 27 missions with actual Phase E operations cost available
  - *Inconsistencies in the data presented challenges in modeling*
  - *Percent rank plots were used to look for trends and attempt to identify potentially incorrectly bookkept data*
  - *The final determined approach was to downselect to the best data*
- Down selected perceived best quality data included 8 missions
  - *3 planetary and 5 EO*
- Effort is continuing in 2022
  - *Examining existing mission data in depth further in attempt to normalize*
  - *Collecting new mission data*
  - *Conducting case study interviews were possible/appropriate*

Mission Type	Phase	Data Source	Missions
Planetary	Cruise w/Checkout	SAP SAP CADRe	OSIRIS-REx MAVEN MESSENGER
	Nominal Cruise	SAP CADRe	OSIRIS-REx MESSENGER
	Flyby/Encounter	N/A	None
	Approach/Orbit Insertion	SAP SAP	OSIRIS-REx MAVEN
	Orbital Operations	SAP SAP CADRe	OSIRIS-REx MAVEN MESSENGER
Earth Orbiting	Checkout	SAP SAP SAP	GPM MMS Fermi
	Orbital Operations	SAP SAP SAP CADRe CADRe	GPM MMS Fermi OCO-2 NuSTAR

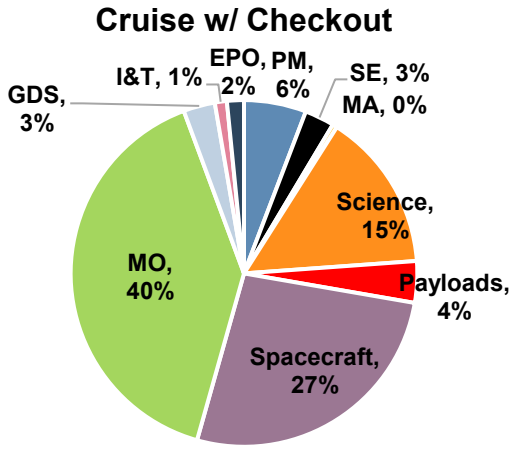
Level 2 WBS Investigation

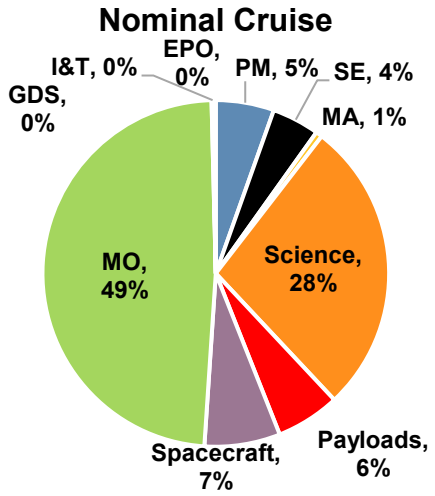
- Percent rank plots for two major Level 2 WBS categories of Science and Missions Operations shown below
- In both graphs there is a noticeable split between planetary and Earth Orbiting (EO) missions
- Some individual missions stand out well above the rest likely due to incorrect bookkeeping
  - *Examples like this were removed*

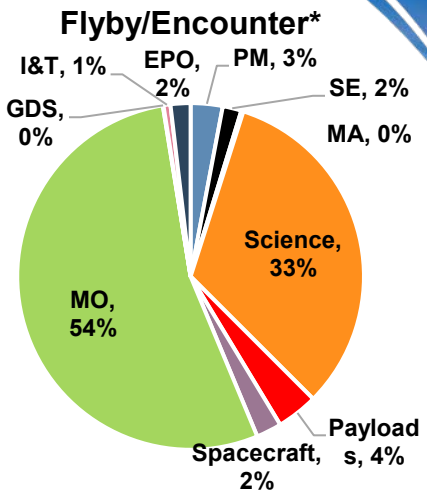




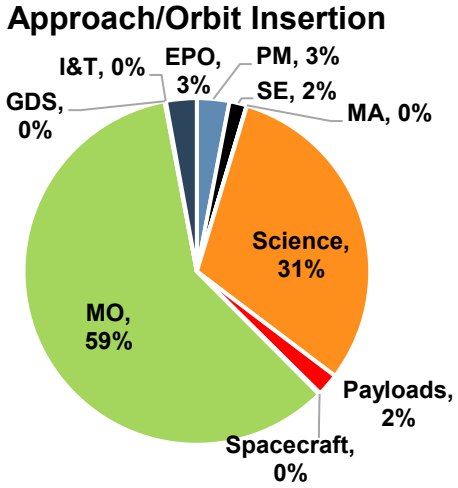
Level 2 WBS Investigation

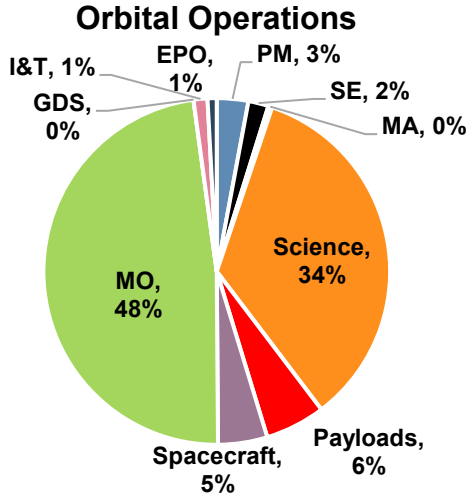






- A proportional allocation model was developed by taking the average percent cost from these 8 missions
- Done for each individual operational phase in the model Percentages are applied to a top level MOCET estimate to derive the Level 2 cost values
- Planetary model is shown at right
- *No data was available for the flyby/encounter phase.
  - *An average was taken of the approach/orbit insertion and orbital operations phases*
  - *Assumed to be a reasonable mix of science and missions operations activities*

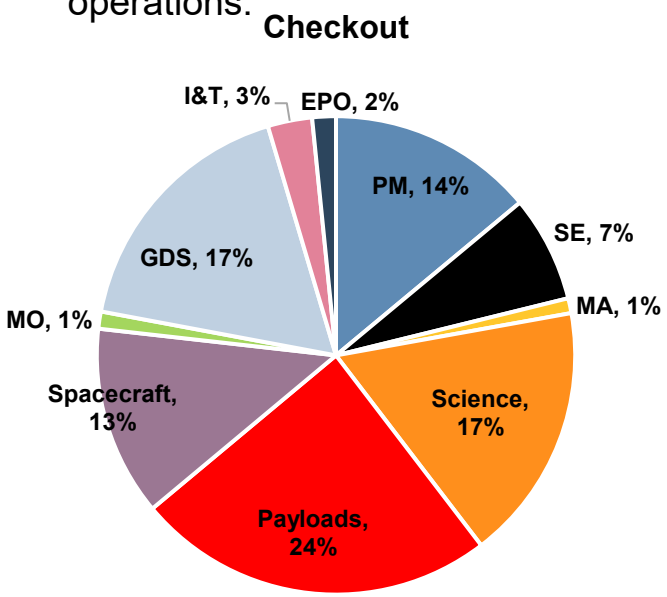


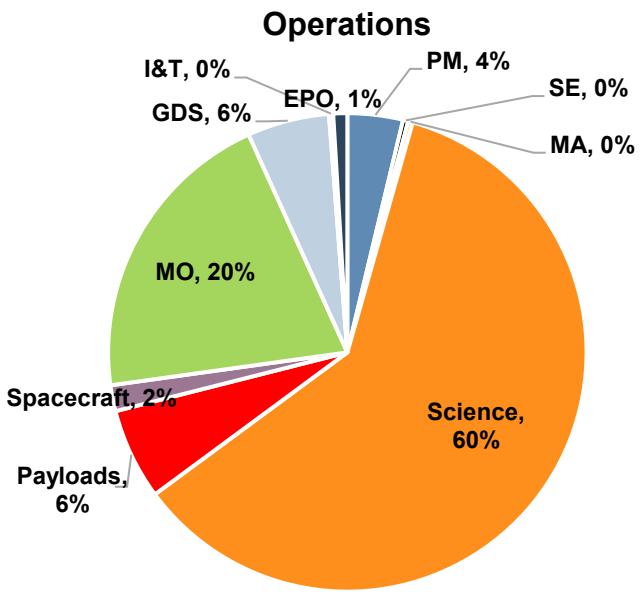


- **Observation**: planetary missions appear to spend more on missions operations, likely because of the remote nature of operations and diversity of operational phases

Level 2 WBS Investigation

- Earth Orbiting (EO) model is shown below
  - **Observation**: unlike planetary missions, EO missions tend to spend the most on science, likely because of the continuous and homogenous nature of operations.



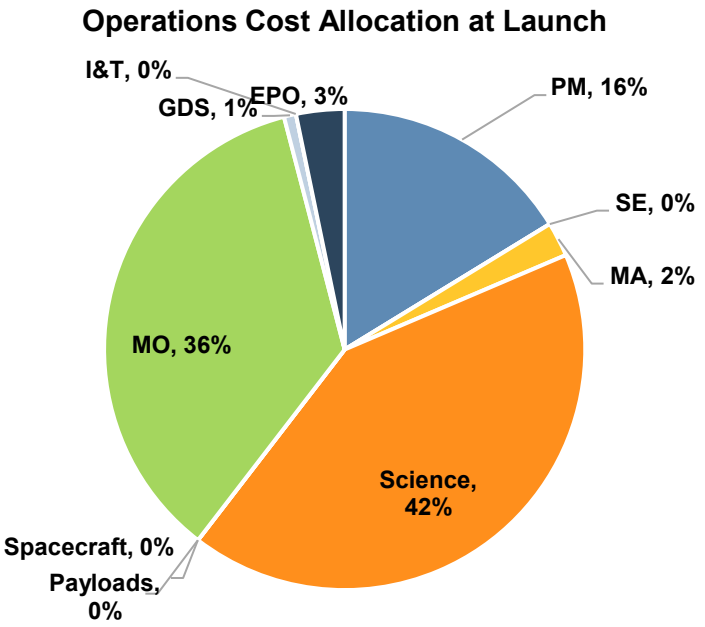


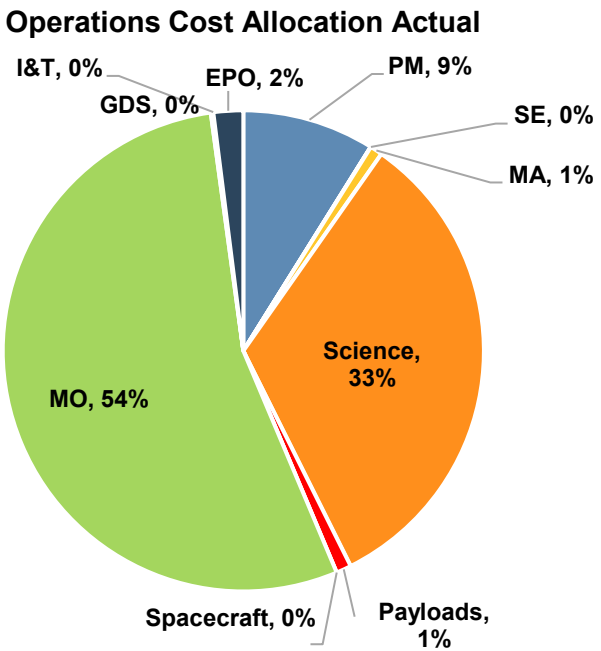
- The results of this proportional allocation model for EO/Planetary model have been compared against final actual costs, as well as proposed costs at Step 2 evaluations
  - *Initial results are encouraging, as potentially this model can be used to identify misallocation of Phase E costs early in the lifecycle*
  - *This model is still however limited including only 8 missions*
  - *Does not cover landed missions or instrument only missions at this time*

Example New Mission Data & Observations

Near Earth Mission

- New data collected this year from a mission not included in the previously developed model shown below





- This is an example of the operations cost at launch versus the actual
  - *This missions required significantly more Missions Operations cost than anticipated at launch due to complexity of operations in the space environment*
  - *Examining other mission characteristics and factors that could drive the need for a different mix of cost elements other than EO vs. Planetary*

Level 2 WBS Investigation

Next Steps

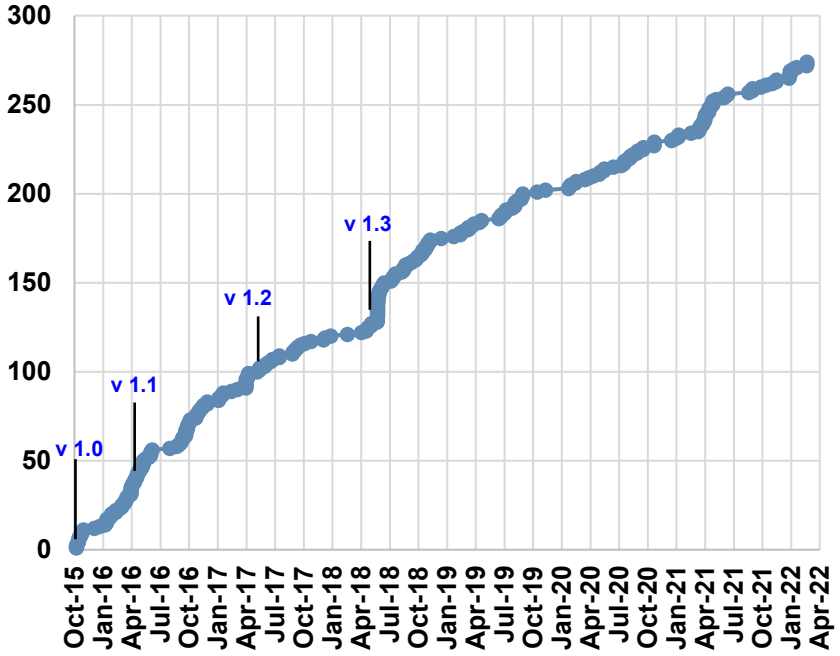
- Continue to investigate Level 2 mission costing
  - *Examine existing mission data in depth further in attempt to normalize*
  - *Collect new mission data*
  - *Conduct case study interviews were possible/appropriate*

- Explore other potential drivers in addition to Planetary versus Earth Orbiting
  - *Some new mission data has shown slightly different results than the current data set*

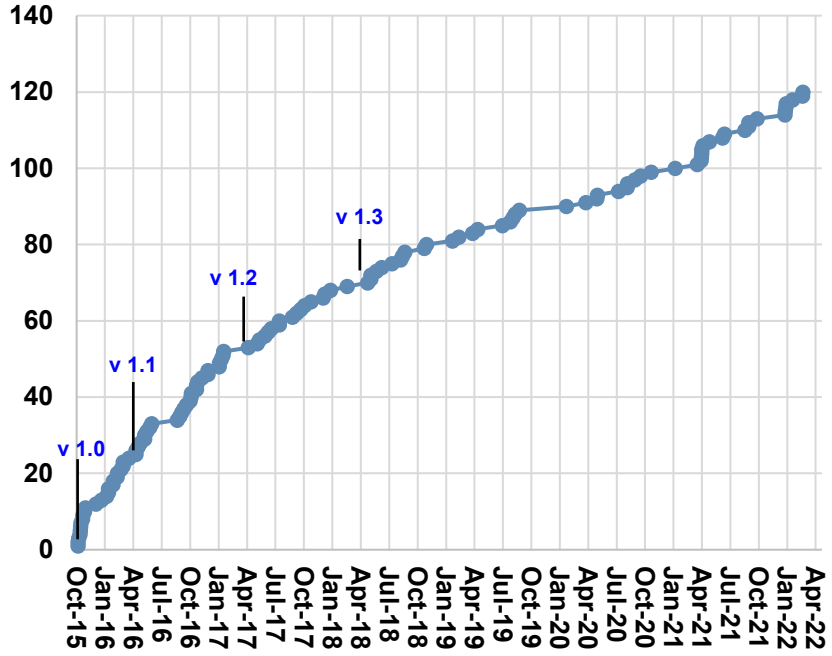
ONCE Downloads and Users

- To date MOCET has been downloaded from ONCE 274* times since the initial release
  - **Downloads include those from inactive users and duplicate downloads*
    - ONCE output generally only shows active users and unique downloads
  - *Version 1.0 - 30, Version 1.1 - 60, Version 1.2 – 37, and Version 1.3 – 147*
- As of April 2022, 120 unique users have downloaded MOCET from ONCE
  - *Since the release of v1.0 the number of users has increased steadily*

Cumulative Downloads

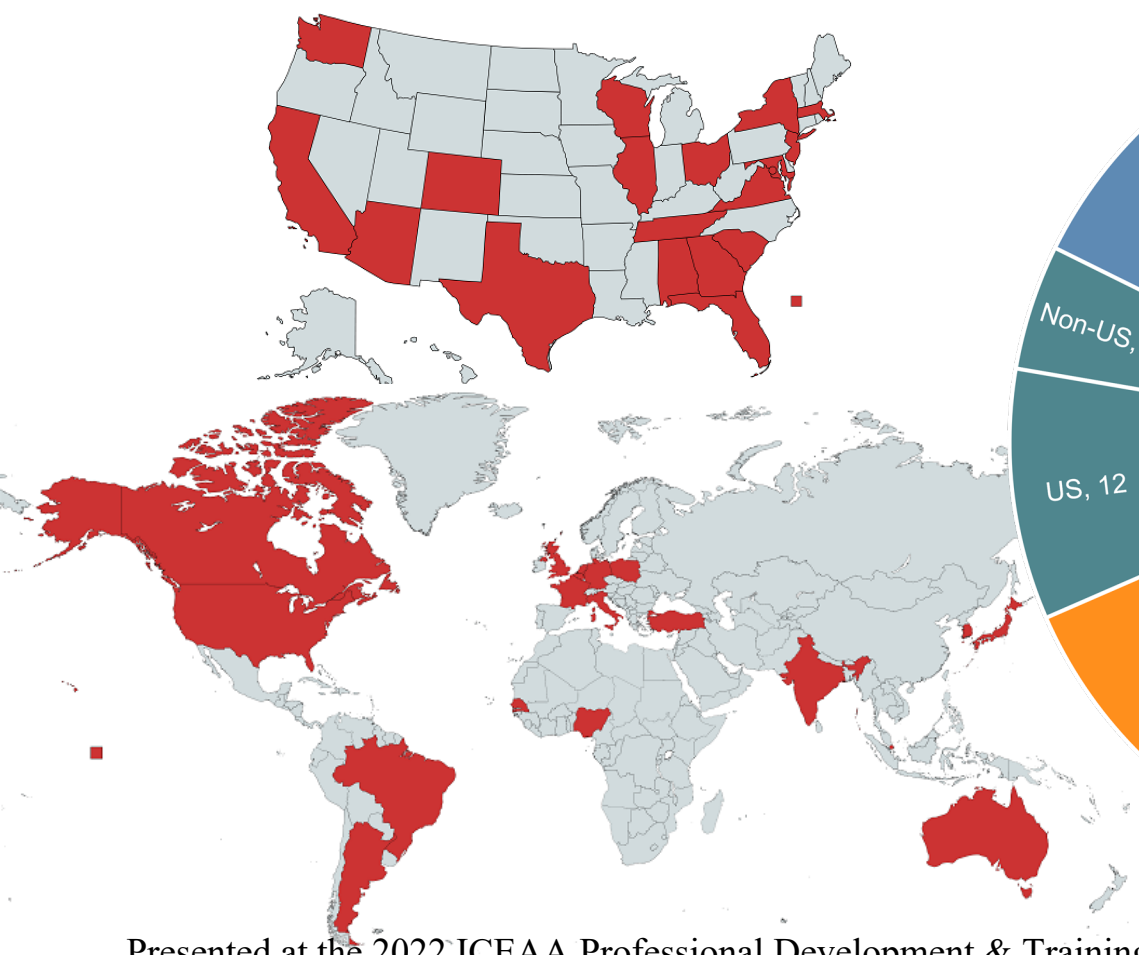


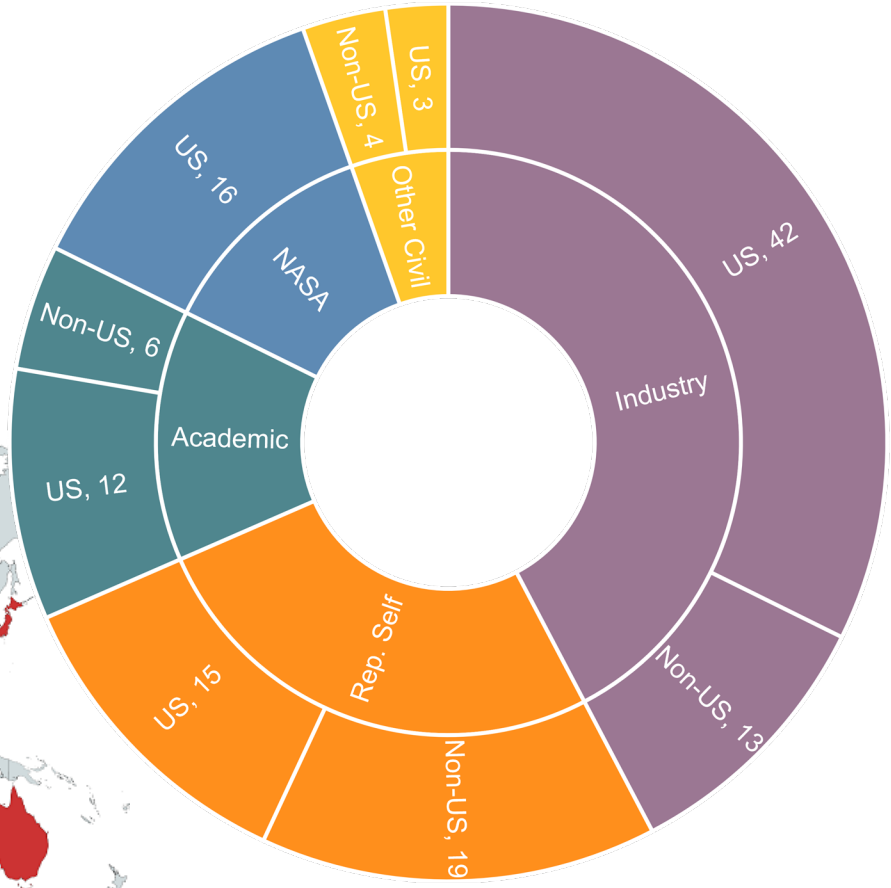
Cumulative Users



software.nasa.gov Downloads and Users

- There are 130 MOCET users on software.nasa.gov since its release there in April of 2017
  - *Most users are from Industry (55), Representing Self (34), Academic (18), and from NASA (16)*
  - *There are also 7 Other Civil/Government*
  - *Of the 130 users, 42 are also international coming from Africa, Asia, Australia, Europe, and South America*





Created with mapchart.net

Conclusion

- Current status of MOCET updates and research has been presented
- MOCET will continue to be periodically updated with new mission data
- Model is currently being used by both evaluators and proposers
- We will continue to engage and grow the user community

Download MOCET
ONCE Model Portal https://oncedata.hq.nasa.gov
Available external to NASA via https://software.nasa.gov

For More Information
Email: MOCET@aero.org

Publications

- Mission Operations Cost Estimation Tool (MOCET) 2020/2021 Updates, 2021 IEEE Aerospace Conference, Big Sky, MT
- Mission Operations Cost Estimation Tool (MOCET) 2020, 2020 IEEE Aerospace Conference, Big Sky, MT
- Mission Operations Cost Estimation Tool (MOCET) Version 1.3 and Beyond, 2019 IEEE Aerospace Conference, Big Sky, MT
- The Mission Operations Cost Estimation Tool (MOCET): Development History and 2018 Updates, 2018 AIAA SPACE and Astronautics Forum and Exposition. Orlando FL
- Mission Operations Cost Estimation Tool (MOCET) v1.3, 2018 NASA Cost and Schedule Symposium, August 2018, Greenbelt MD
- Mission Operations Cost Estimation Tool (MOCET), 2017 IEEE Aerospace Conference, Big Sky, MT
- Mission Operations Cost Estimation Tool (MOCET) FY17 Update, 2017 NASA Cost and Schedule Symposium, August 2017, Washington DC
- Mission Operations Cost Estimation Tool (MOCET) Update, 2016 NASA Cost Symposium, August 2016, Cleveland OH
- Mission Operations Cost Estimation Tool (MOCET), 2015 NASA Cost Symposium, August 2015, Mountain View CA