Water and Energy in the Atmosphere

Particles in the Atmosphere

Large-scale Mass Redistribution

CLOUDS, CONVECTION AND PRECIPITATION
Water and Energy in the Atmosphere

AEROSOLS
Particles in the Atmosphere

MASS CHANGE
Large-scale Mass Redistribution

SURFACE BIOLOGY AND GEOLOGY
Earth Surface & Ecosystems

SURFACE DEFORMATION AND CHANGE
Earth Surface Dynamics

INTERCONNECTED CORE MISSIONS

EARTH SYSTEM OBSERVATORY
EARTH SYSTEM OBSERVATORY

INNOVATION & COMPETITION
EARTH EXPLORER MISSIONS

Snow Depth and Water Content
3D Ecosystem Structure
Ocean Surface Winds and Currents
Greenhouse Gases
Ozone and Trace Gases
Atmospheric Winds
Ice Elevation
NASA Earth Action Strategy

New Earth Information Center

Earth Action Solutions for Impact

Earth System Science & Applications Incubation

Earth System Observations
Mass Change Mission Collaboration

• Mass Change is 1 of 5 Designated Observables in the 2017 Decadal Survey
  • NASA and International partners are collaborating to implement the next gravity/mass change mission

• The goal of the agencies is to materialize the Bender constellation, shown to meet science and societal objectives described in 2015 paper (Pail et. al.) and by the IUGG Expert Panel *
  • The agencies built on a successful legacy of previous missions: GRACE & GRACE-FO by NASA and DLR, and GOCE by ESA
  • The project will report today on their status and plans

• MC is one of the four missions of the Earth System Observatory (ESO).
  • NASA works to integrate the ESO missions by leveraging engineering, science, data systems and applications capabilities
    • ESO integration will enable multi-disciplinary and interdisciplinary research, and augment the missions’ community of practice

OPENING REMARKS
Bernie Bienstock, Mass Change Project Office
Welcome………………………………………………………………… Julie Robinson / NASA HQ
Introduction……………………………………………………………… Lucia Tsaoussi / NASA HQ
Opening Remarks…………………………………………………………. Bernie Bienstock / JPL, Caltech
Overview…………………………………………………………………… Mike Gross / JPL, Caltech
DLR – P1 Status……………………………………………………………. Michael Nyenhuis / DLR
ESA – P2 Status…………………………………………………………… Ilias Daras / ESA
Science……………………………………………………………………… David Wiese / JPL, Caltech
Mission Implementation………………………………………………… André Girerd / JPL, Caltech
Summary…………………………………………………………………… Mike Gross / JPL, Caltech
Community Discussion / Questions…………. Moderated by David Wiese / JPL, Caltech
Mass Change Development

- Mass Change (MC) DO study began in October 2018
- Continued through 2019, 2020, until May 2021 – hosted town halls at the past 3 AGUs
- Developed the SATM, including vetting by the community
- Defined architecture classes, with science value metrics for each
- Studied predicted life of GRACE-FO to meet the continuity requirements of the DS
- Assessed technology readiness, risks and maturation plans
- Identified potential international partnerships and began dialogues with each
- Produced a comprehensive final report in July 2021, summarized in AGU publication*

Identified High-Level Architectures

The MC study team analyses included:

- NASA Headquarters (HQ) guidance and constraints
- Decadal Survey (DS) recommendations
- Community input
- Technology readiness
- High-level cost estimates
- International partner interest, capabilities, and readiness

The highest-value architectures were identified to

- Provide acceptable levels of DS recommended science, as judged by the community
- Include technology elements that can be matured within the MC timeframe
OVERVIEW
Mike Gross, Mass Change Project Manager
Mature Mass Change (MC) Mission Concept

- Implementation and operation architecture is same as GRACE/GRACE-FO
- Division of responsibilities between US (NASA) and Germany (DLR) is the same as GRACE-FO
- Launch is currently planned for Late 2027/Early 2028
- Continuity of the gravity record is fundamental
MC and GRACE-FO Architectures are Nearly Identical
Project Implementation Maturity Beyond Typical for Phase-A

- MC currently has baselined the same satellite-satellite tracking implementation as GRACE-FO
  - Laser Ranging Interferometer (LRI) replaces Microwave Ranging Instrument
  - Gravity fields derived from LRI tech demo on GRACE-FO are consistent with those derived from MWI, while offering improved performance at high frequencies (Pie et al., 2021; Peidou et al, 2021; Ghobadi-Far et al., 2020)

- Approaches to ACC redundancy will be assessed in Phase A, including potential contribution from ESA

- Major Project Milestones (all are current estimates and might change)
  - System Requirements Review/Mission Design Review (SRR/MDR) - March 2023
  - Preliminary Design Review (PDR) – February 2024
  - Critical Design Review (CDR) – April of 2025
  - Assembly, Integration and Test (AIT) – October 2026
  - Launch – Currently planned for Late 2027/Early 2028.
MASS CHANGE

EARTH SYSTEM OBSERVATORY

DLR – P1 STATUS
Michael Nyenhuis,
DLR Mass Change Project Manager
Continue US-D partnership on mass transport monitoring

- Germany shares NASA’s ambitions to continue mass transport monitoring as one of five top priorities in EO for the next decade highlighted in the NASA Earth Science Decadal Survey Report.
- To continue the very successful technological and scientific GRACE/GRACE-FO partnership Germany initially proposed a joint US-D MC/GRACE-I mission combining
  - a quickly realized single-pair GRACE-FO successor based on redundant LRI SST with launch in 2027 into a polar orbit to guarantee data continuity, and
  - an (optional) ICARUS payload (International Cooperation for Animal Research Using Space) which globally monitors animal movements as biodiversity indicator.
- Germany supports NGGM* in the Mission of Opportunity element of ESA’s FutureEO program as the second component of a double pair mission (P1/P2 staggered approach).

* NGGM = Next Generation Gravity Mission
MC/GRACE-I Phase A study results (Apr-Sep 2022)

Detailed Mission Analysis (funded by BMBF, Lead by GFZ, supported by DLR, close collaboration with NASA/JPL and ESA)

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Option 1a (2 ACC techdemo)</th>
<th>Option 1b (radio occultation)</th>
<th>Option 3a / 3b (Analogue to 1a/1b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grace-FO heritage (Option 1)</td>
<td>Redundant LRI 3 ACC (GRACE-FO type) GNSS Receiver no additional payloads</td>
<td>Redundant LRI 3 ACC (GRACE-FO type) GNSS Receiver 4th ACC microSTAR type</td>
<td>As option 3 + 4th ACC techdemo And/Or + RO instrument</td>
</tr>
<tr>
<td>Propulsion</td>
<td>Heritage Cold Gas System High density gas (Krypton) EP techdemo for orbit maintenance</td>
<td>Heritage Cold Gas System High density gas (Krypton) EP techdemo for orbit maintenance</td>
<td>Heritage Cold Gas System High density gas (Krypton) EP techdemo for orbit maintenance</td>
</tr>
</tbody>
</table>

- Two satellites based on GRACE-FO with technical enhancements
  - Partly redundant LRI as SST instrument
  - Improved acceleration measurement (redundant ACCs based on GRACE-FO superSTAR or “adapted microSTAR”)
  - Heritage cold gas thrusters, potential improvements (hybrid concept with EP) discussed
- Optional payloads
  - ICARUS to detect animal movements (operational biodiversity monitoring in parallel to variations in the global water cycle)
  - Radio occultation (RO) instrument
- Discarded options
  - Low-shock cold gas thrusters
  - MicroSTAR (4th ACC) and Quantum gravity gradiometer (QGG) tech demos
MC/GRACE-I Phase A study results (Apr-Sep 2022)
Detailed Mission Analysis (funded by BMBF, Lead by GFZ, supported by DLR, close collaboration with NASA/JPL and ESA)

- Joint effort: 3 TIMs & PRR (Preliminary requirements review) co-location involving NASA/JPL and ESA
- Identified **synergies and commonalities of MC/GRACE-I and NGGM** (i.e. P1 and P2 in MAGIC) in cooperation with ESA
- Successful PRR in Sep 2022 with key recommendations:
  - Technical showstoppers have not been identified. The results of the PRR permit the transition into Phase B.
  - **NASA/JPL and DLR to harmonize programmatic boundary conditions** for a joint mass change mission: requirements baseline, redundancy concept (ACC/LRI), PA-approach, launcher strategy, NGGM/MAGIC framework and implementation schedule. Harmonization with ESA with regard to the MAGIC cooperation is strongly recommended.
  - To meet the expectations and needs of the scientific community for continuity and - in the frame of MAGIC - enhanced spatial / temporal resolution of mass transport products a **minimum lifetime of 5 years** (goal: 7 years) needs to be achieved.

German Parliament has approved the budget to allow implementation of baseline option of “MC/GRACE-I” without ICARUS or RO

- GRACE-FO re-built with enhancements and LRI as primary SST technology
- Start of Phase B/C/D for German contributions required in 2023
Ilias Daras,
ESA NGGM/MAGIC Mission Scientist
MAGIC An international constellation for mass change science and applications

- **MAss-change and Geosciences International Constellation (MAGIC)** is the joint NASA/ESA two-pair “Bender-type” constellation concept based on NASA’s MCDO and ESA’s NGGM (Next Generation Gravity Mission).

- **Enhanced continuity** after GRACE-FO ensured to preserve climate series, per US Decadal Survey 2018

- Strong user demand expressed by IUGG, IAG, GGOS for improved temporal and spatial resolutions and accuracy in enhanced continuity of observations, paving the way to future sustained observations

- Goal is to implement a pre-operational mission with improved observations to meet science and application objectives outlined in ESA/NASA MAGIC Mission Requirements Document (MRD).
First satellite pair (P1) - Mass Change / GRACE-I

- Implemented via a US-Germany fast-paced cooperation programme to ensure continuity of observations with GRACE-FO, with potential ESA in-kind contributions for a new generation of accelerometers

Second satellite pair (P2) – NGGM

- Nov. 2022 ESA’s Council at Ministerial level resolved that FutureEO-1 programme will include the start of the development of NGGM/MAGIC in cooperation with NASA

- Implemented via Europe-US cooperation programme with potential NASA in-kind contributions for a redundant Laser Ranging Instrument

- Inclined controlled orbit with a target altitude of \(~400\) km and inclination between \(65\) deg and \(70\) deg, forming a “Bender constellation” to mitigate spatio-temporal aliasing errors

- Target launch aiming to maintain a minimum of 4 years of combined operations between P1 and P2

- MicroSTAR family accelerometers developed by ONERA for ESA with GOCE-like performance

- Hybrid propulsion concept: electric propulsion for orbit maintenance & drag compensation, linear cold gas thrusters for fine attitude control/drag compensation
GRACE and GRACE-FO: 20 years of Amazing Discoveries
Basis for Being Foundational

“Ensures continuity of measurements of groundwater and water storage mass change, land ice contributions to sea-level rise, ocean mass change, ocean heat content (when combined with altimetry), glacial isostatic adjustment, and earthquake mass movement. Also important for operational applications, including drought assessment and forecasting, hazard response, and planning water use for agriculture and consumption.”

-Table 3.5; 2017 Decadal Survey
Overlap with GRACE-FO Drives FY28 MC Launch

- MCDO Study Team assessed the probability of different observing system architectures to provide overlap with GRACE-FO
  - Heritage architecture (single in-line pair with a free-drifting orbit) was found to have highest probability of providing overlap
  - GRACE-FO reliability is 50% by June 2028 (50% launch readiness date)

- GRACE-FO project continues monitoring health and potential end of life date
  - Single string on accelerometer and IPU (GNSS receiver and MWI tracking)
  - Consumables and space environment likely put end of mission in 2027-2030 timeframe
    - Current Solar Cycle 25 is above-average strength, implying relatively fast orbit decay and reduced lifetime (MCDO Study used a more benign solar cycle prediction in lifetime assessment)
    - Thruster leaks and uncertainty in future leak evolution
    - Operational decisions being made to simultaneously maximize quality of science data products considering accelerometer transplant, and to extend mission lifetime

- Desired to have a minimum 6 months of overlap with GRACE-FO
  - Vital for calibration of GRACE-FO accelerometer transplant and the resulting 10-year mass change data record (2018-2028)
Mass Change Science and Applications at a Glance

- Sea Level
- Ice Sheet Mass Balance
- Ocean Heat Uptake
- Ocean Circulation
- Global Water Cycle
- Glacial Isostatic Adjustment
- Landscape Changes
- Freshwater Storage
- Groundwater Recharge and Storage
- Drought Monitoring
- Hazard Monitoring and Response
- Crop Yield
- Forest Health
- Fire Risk
- Seasonal Weather Prediction
- Earthquakes
- Drought Severity
- Flood Vulnerability
- Earthquake Monitoring
- Hazard Monitoring and Response
- Groundwater Recharge and Storage
- Glacial Isostatic Adjustment
- Landscape Changes
- Ocean Heat Uptake
- Ocean Circulation
- Global Water Cycle
- Climate Variability and Change
- Global Hydrological Cycle and Water Resources
- Earth Surface and Interior
- Societal Application

Decadal Survey Priority
- Most Important
- Very Important
- Important

Mass Change AGU 2022 Town Hall
Decadal Survey Science and Application Objectives for Mass Change

Measurement Parameters for Baseline

Baseline Observing System – supports full science objectives

Climate Variability and Change

- C-1a: (300 km)²; 15 mm Monthly
- C-1c: (300 km)²; 40 mm Monthly
- C-1b: (300 km)²; 15 mm Monthly
- C-1d: (300 km)²; 15 mm Monthly

Global Hydrological Cycles and Water Resources

- H-1a: (1000 km)²; 10 mm Monthly
- H-2c: (450 km)²; 25 mm Monthly
- H-3b: (450 km)²; 25 mm Monthly
- H-4c: (450 km)²; 25 mm Monthly

Earth Surface and Interior

- S-1b: (300 km)²; 25 mm Monthly
- S-3a: (300 km)²; 25 mm Monthly
- S-4a: (300 km)²; 25 mm Monthly
- S-5a: (20,000 km)²; 1 mm Monthly

Decadal Survey objective number

Utility

G: Global
O: Ocean
L: Land
I: Ice

Key Variable

SR = Spatial Resolution; ACC = Accuracy; TR = Temporal Resolution

Weight = Importance x Utility

C: Continuity explicitly recommended in DS

Legend

Utility

H: High 1.0
M: Medium 0.67
L: Low 0.33
VL: Very Low 0.10

Baseline Observing System – supports full science objectives

Science Performance Targets

MC Utility Score

H: High 1.0
M: Medium 0.67
L: Low 0.33
VL: Very Low 0.10

Mass Change AGU 2022 Town Hall
Decadal Survey Science and Application Objectives for Mass Change

Measurement Parameters for Baseline

Baseline Observing System – supports full science objectives

**Climate Variability and Change**

- C-1a: (300 km)$^2$; 15 mm; Monthly
- C-1b: (300 km)$^2$; 15 mm; Monthly
- C-1c: (300 km)$^2$; 40 mm; Monthly

**Global Hydrological Cycles and Water Resources**

- H-1a: (1000 km)$^2$; 10 mm; Monthly
- H-2c: (450 km)$^2$; 25 mm; Monthly
- H-3b: (450 km)$^2$; 25 mm; Monthly

**Earth Surface and Interior**

- S-1b: (300 km)$^2$; 25 mm; Monthly
- S-3a: (300 km)$^2$; 25 mm; Monthly
- S-4a: (300 km)$^2$; 25 mm; Monthly
- S-5a: (20,000 km)$^2$; 1 mm; Monthly

**MC Measurement Parameters**

- MC measurement parameters provide consistency in the quality of science data products established by GRACE and GRACE-FO

**Legend**

- G: Global
- O: Ocean
- L: Land
- I: Ice
- SR = Spatial Resolution; ACC = Accuracy; TR = Temporal Resolution

**MC Utility Score**

- H: High 1.0
- M: Medium 0.67
- L: Low 0.33
- VL: Very Low 0.10

**Science Performance Targets**

<table>
<thead>
<tr>
<th>Decadal Survey objective number</th>
<th>1</th>
<th>S-4a: (300 km)$^2$; 25 mm; Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Variable</td>
<td>C</td>
<td>SR: ACC; TR</td>
</tr>
<tr>
<td>Utility</td>
<td>M</td>
<td>G</td>
</tr>
<tr>
<td>Weight</td>
<td>1.0</td>
<td>Importance x Utility</td>
</tr>
</tbody>
</table>

**Decadal Survey Science and Application Objectives**

- Most Important
- Very Important
- Important
- Lower Weight

**Baseline**

- Most Important: Highest weight
- Very Important: Medium weight
- Important: Lower weight
- Lower Weight: Lowest weight
MC Applications Community Assessment

**Goal**: Maximize the return on investment of current and future MC missions by enhancing their applications value and societal benefits

- Two communities
  - **Community of Practice**: assessed through survey and workshops
  - **Community of Potential**: Led by RTI International, through a series of discussion panels and interviews with representatives from private industry and public agencies
MC Community of Practice

### April 2020

**Applications Domains of Survey Respondents**

<table>
<thead>
<tr>
<th>Water Resources</th>
<th>Agriculture</th>
<th>Ocean/Sea Level Rise</th>
<th>Cryosphere</th>
<th>Solid Earth</th>
<th>Other</th>
<th>Weather Services</th>
</tr>
</thead>
</table>

87 responses

<table>
<thead>
<tr>
<th>Spatial Resolution</th>
<th>Temporal Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>Daily</td>
</tr>
<tr>
<td>1/2</td>
<td>Weekly</td>
</tr>
<tr>
<td>3/4</td>
<td>Monthly</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum Latency</th>
<th>Accuracy (equivalent height of water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>2-5 cm</td>
</tr>
<tr>
<td>1/2</td>
<td>&lt; 1 cm</td>
</tr>
<tr>
<td>1/2</td>
<td>1-2 cm</td>
</tr>
</tbody>
</table>

**Table 1. Select questions from MC Applications Survey**

- **Desired Spatial Resolution**: GRACE terrestrial water storage data have a resolution no better than 3° x 3° latitude/longitude (~100,000 km²), with some assimilated products at 0.125° resolution. Are those spatial resolutions adequate? If no, what spatial resolution would you require/prefer for your application?
- **Desired Temporal Resolution**: GRACE terrestrial water storage data are typically provided as monthly means, with some assimilated products updated weekly. Are those temporal resolutions adequate? If no, what temporal resolution would you require/prefer for your application?
- **Desired maximum Latency**: GRACE terrestrial water storage products were released with roughly 2-to-4-month latency, while some assimilated products had 2-to-8-day latency. Are those timely enough for your application? If no, what latency would be sufficient?
- **Desired Accuracy**: GRACE terrestrial water storage data have an uncertainty of roughly 1.5 cm equivalent height of water over a 100,000 km² area. What accuracy or precision is required to be useful for your application?

Data Assimilation Frameworks can satisfy needs of majority of users

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MC Community of Potential
Capturing and aggregating anecdotal interview results

Temporal Resolution Needs

Estimated Temporal Resolution Needs

<table>
<thead>
<tr>
<th>Interval</th>
<th>State, Local, and Regional Water Management</th>
<th>Electric Utilities Water Management</th>
<th>Water Utilities</th>
<th>Agricultural Irrigation</th>
<th>Water Sourcing for Products</th>
<th>Corporate Sustainability</th>
<th>Geohazard Risk Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraday</td>
<td>drought emergency declarations</td>
<td>soil moisture</td>
<td>snowpack</td>
<td>water risk</td>
<td>water level and streamflow</td>
<td>groundwater and water flow models</td>
<td>flood risk projections</td>
</tr>
<tr>
<td>Daily</td>
<td></td>
<td>precipitation and streamflow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly</td>
<td></td>
<td>evaporation water loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly</td>
<td></td>
<td>river or reservoir bathymetry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quarterly</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every 3–5 Years</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Decadal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Spatial Resolution Needs

Observed Land/Water Area Preferences (from Interviews)

- 10 m²
- 100 m²
- 1 km²
- 10 km²
- 100 km²
- 1,000 km²
- 10,000 km²

- groundwater flow models
- aquifer level
- operational plant level; any water measurements
- reservoir drainage areas
- drought monitoring for watershed management
- municipality and aquifer levels
- N/A—not a large driving factor
- manufacturing site selection
- water ecosystem management
- manufacturing operations
- water consumptive use
- watershed replenishment planning
- Property or street level
MC Measurement System Requirements

- Compliance with the Decadal Survey is ensured by placing an overarching requirement on the MC measurement system performance

Requirements are met across all harmonic degrees

Adding temporal aliasing error to measurement system error

All MC SATM Measurement Parameters are met, ensuring responsiveness to the Decadal Survey Science Objectives
MISSION IMPLEMENTATION
André Girerd
Mass Change Project Systems Engineer
Spacecraft Leverages Heritage

The system performance requirements for the Mass Change mission are identical to the performance requirements of GRACE-FO.

Maintenance of true heritage of the GRACE-FO system allows for a minimization of cost and risk and a maximization of the probability of success.

Changes to the Mass Change system are under consideration for the following categories:

- Removal of Microwave Instrument (MWI)
- Accommodation of LRI Scale Factor Unit
- Redundancy options
- Resolution of issues discovered on the GRACE-FO mission
- Utilization of current generation of Airbus spacecraft
Heritage of Configuration

- Elimination of the Microwave Instrument for the Mass Change Mission results in GRACE like component spacing and higher radiator margins.
Heritage Spacecraft Platform

- **CHAMP**
  - Launched 2000

- **GRACE**
  - Launched 2002

- **GRACE Follow-On**
  - Launched 2018

- **GOCE**
  - Launched 2009

- **Cryosat 2**
  - Launched 2010

- **SWARM**
  - Launched 2013

- **Sentinel-6 (MF)**
  - Launched 2020

**Mass Change**
- **Planned 2027**

*Mass Change AGU 2022 Town Hall*
Laser Ranging Interferometer is Proven

**Scale Factor Unit (SFU)**
Measures the change of the laser frequency over long durations by relating the USO clock to the cavity Free-Spectral Range (TRL 6)

**Ultra Stable Oscillator (USO):**
Provides the stable 40 MHz clock to LRP, SFU, and 10 MHz to GNSS (TRL 7)

**Optical Cavity (CAV):**
Passive resonator used to stabilize the laser frequency on spacecraft in the Reference role (TRL 7)

**Optical Bench Electronics (OBE):**
Powers the steering mirror and photoreceivers and provides signal conditioning for the science signal (TRL 7)

**Laser Ranging Processor (LRP):**
Measures the interferometer phase and records the science signal; Laser frequency stabilization electronics; Commands the steering mirror angle for acquisition and tracking. Secondary power for OBE, LAS, CAV (TRL 7)

**Optical Bench Assembly (OBA):**
Includes the quadrant photoreceiver (QPR), fine steering mirror (FSM), and main interferometer optical bench (TRL 7)

**Baffles + Light Path Closures (BAF+LPC):**
Baffles and Light Path Closures ensure unobstructed field view and protect the system against ATOX (TRL 7)

**Triple Mirror Assembly (TMA):**
Three mirror CFRP “virtual” corner-cube retroreflector. Routes the laser beams around the fuel tanks (TRL 7)

**Laser (LAS):**
Provides 25 mW of 1064nm light; frequency stabilized to the optical cavity (reference), or to the incoming light (transponder) (TRL 7)

**EARTH SYSTEM OBSERVATORY**

Mass Change AGU 2022 Town Hall
SUMMARY
Mike Gross, Mass Change Project Manager
Summary

• International Partnership with Germany has lead to the success of GRACE and GRACE-FO, and continues to be enabling for the success of Mass Change

• The MC Project has made a tremendous amount of progress over the last year

• The end-to-end system has high heritage of both the design and the team
  • Ensures high probability of an on-schedule launch
  • Minimizes risk to loss of continuity of the gravity record

• NASA, ESA, EC (European Commission), DLR, ASI, CNES and other Agencies continue to discuss approaches to establishing a long-term international plan for sustained gravimetry observations beyond MC and NGGM
COMMUNITY QUESTIONS/DISCUSSION
David Wiese, Mass Change Science