A NASA Engineering and Safety Center (NESC) Technical Assessment

The NASA Jitter Handbook Development Activity: A Multidisciplinary Collaborative Effort

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Talk Abstract

Predicting, managing, controlling, and testing spacecraft line-of-sight (LoS) jitter caused by micro-vibrations from on-board internal disturbance sources is a formidable multidisciplinary engineering task. Spaceflight mission hosting high-performance vibration-sensitive optical sensor payloads with stringent pointing stability requirements are especially challenged in this area.

Across the spaceflight community of practice jitter engineering is a known engineering challenge area with relatively few practitioners and limited subject matter experts. Exacerbating this situation is the fact that there are no established/documented NASA jitter engineering guidelines available. Here we cite a key finding from a 2019 NASA-sponsored Spacecraft LoS Jitter Workshop: *There is no generally engineering reference document with guidelines and best practices for managing and mitigating spacecraft jitter.* Clearly both government and industry would benefit from such jitter engineering guidelines, not only for design purposes, but also for workforce education by collecting/documenting technical insights on jitter analysis and test methods as well as operational considerations.

While some textbooks and references in the aerospace literature may touch on the subject of jitter, important details of specific flight proven methodologies and techniques used by today's jitter practitioners are not readily accessible. Much of this knowledge is treated as proprietary information across industry and is often closely held by the various spacecraft engineering organizations. However, the belief of the handbook team is that there is much basic jitter engineering 'tribal knowledge' that can be captured without compromising any organization's proprietary information.

The Nation Aeronautics and Space Administration (NASA) is planning technically aggressive missions that include high-performance optical payloads with delicate, highly vibration-sensitive scientific instruments. For example, the planned Habitable Worlds Observatory (HWO) is a concept for a mission to identify potentially habitable planets around other stars, closely examining their atmospheres to determine if life could possibly exist. The undoubted challenges of jitter for the HWO mission are one of many motivations for the creation of a NASA Jitter Handbook that will capture design, analysis, test, and operational best practices and guidelines.

The NASA Engineering and Safety Center (NESC) recently received approval to kickoff a year-long activity to develop a NASA Jitter Handbook which would include lessons learned and best practices for design, analysis, and test, along with operational guidelines to mitigate jitter. The NASA Technical Fellow for GNC has assembled a handbook development team of recognized jitter subject matter experts from across the NASA Enterprise, including support contractors. A senior-level Technical Advisory Group (TAG) has also been formed to provide guidance and insight through periodic reviews of interim handbook products.

At the highest level the handbook will address the questions: What is jitter? When does jitter matter? This will involve examinations of different mission classes/types, their GNC/Pointing System architectures, and their associated pointing stability performance requirements. Beyond this the team envisions a handbook that would equally balance the detailed analysis aspects of jitter and the associated forms of jitter testing, from component-level disturbance characterization testing to full-up system dynamic interaction testing. In addition, one of the primary goals of this initiative is to converge on common jitter engineering terminology, across the multiple disciplines and organizations involved. Converging on and documenting a single set of common terminology that all involved parties in the community—government Agencies, industry partners, and academia—can understand and use will be a major contribution of the handbook. Other aspects of jitter that the handbook would attempt to address include, but are not limited to: defining units and coordinate systems, identifying preferred practices for performing standard checks of the structural Finite Element Models (FEMs), along with the definition of and recommended application of Model Uncertainty Factors (MUFs). Techniques for specifically identifying the necessary features for developing a structural FEM to be used primarily for jitter analysis, compared to those FEMs required and created for the more commonly performed launch vehicle coupled loads analysis, would be covered. The team also recognizes that documenting the best practices for generating a reduced-order state-space model to be used in jitter analysis from the full-order structural FEM (e.g., frequency cutoff) is an important subject to include in the handbook. Lastly, it should be mentioned that the findings and recommendations from the 2019 NASA-sponsored Spacecraft LoS Jitter Workshop as a starting point for handbook development [Ref. 1].

The handbook development team recognizes that not only will the handbook require multidisciplinary inputs (beyond the boundaries of the GNC discipline) but also would benefit from collaboration with other organizations with jitter experience. Thus, the intention is to ensure the development of this new NASA Jitter Handbook is a collaborative effort. As such the handbook team is intending to leverage the experience and knowledge of representatives not only from NASA and its support contractors but its industrial partners, independent consultant subject matter experts, members of academia and other governmental organization.

The handbook team envisions timely knowledge transfer from, among other missions, the James Webb Space Telescope's (JWST) unprecedented success in this area. Some of the other missions where the team expects to extract lessons learned and best practices include, but is not limited to, the Roman Space Telescope (RST), the Hubble Space Telescope (HST), the Geostationary Operational Environmental Satellites (GOES), the Joint Polar Satellite System (JPSS), the Solar Dynamics Observatory (SDO). There is a near term opportunity (and some degree of urgency) to capture the knowledge of senior jitter subject matter experts who are near retirement and/or recently retired.

References

1) Spacecraft Line-of-Sight Jitter Management and Mitigation Lessons Learned and Engineering Best Practices, Cornelius J. Dennehy, Aron A. Wolf, and Davin K. Swanson, NASA/TM−20210017871, June 2021

Presentation Outline

- Presentation Objectives
- Bottom Line Up Front
- Jitter Problem Description
- Multiple Jitter Engineering Challenges
- NASA Jitter Workshop (October 2019): Key Recommendation
- Habitable Worlds Observatory (HWO): A Mission with Stringent Jitter Requirements
- Frequency Spectrum of Jitter Causing Disturbances
- Qualitative/Quantitative Assessment of Difficulty of Meeting Jitter Requirements
- Envisioned Handbook Framework
- Key NASA Stakeholders
- Envisioned Jitter Case Studies
- Technical Activities Plan (including schedule)
- **Some Possible Steps Forwards for Collaboration**
- Additional Information: Backup Charts

Presentation Objectives

- **Introduce this audience to our plans for developing the NASA Jitter Handbook covering Design, Analysis, Test, and Operational Guidelines**
- **Briefly review motivation for this Jitter Handbook and our approach for the Handbook development**
- **Obtain feedback from this audience regarding their perspectives**
  - **The NASA team is very interested in collaborative interaction with the broader community on this important topic**

Bottom Line Up Front

- Jitter is a mission-level, multi-discipline system engineering challenge, that, if not appropriately addressed can have significant technical, cost, and schedule impacts for a mission. Future NASA missions, both ultra high-precision — e.g., Habitable Worlds Observatory (HWO) — and more modest pointing missions, will potentially be at risk.
- Currently a NASA-centric unclassified Handbook but open for expanded participation. NASA has no established engineering reference document with guidelines and best practices for managing and mitigating spacecraft jitter.
- Jitter is a niche engineering area with few NASA subject matter experts (SMEs) and no established pipeline for the future.
- An early NESC jitter workshop recommended that NASA should develop a Jitter Engineering Guidelines handbook documenting lessons learned and best practices for managing and mitigating spacecraft jitter. Intent is to educate, provide insights, capture best practices, and provide a standard reference for discussion.
- This discipline-advancing assessment will develop an initial version: *NASA Jitter Handbook: Design, Analysis, Test, and Operational Guidelines* informed by several relevant NASA case studies .
- This will be a resource primarily for jitter engineering practitioners. However, it can serve multiple audiences: (1) early-to-mid career discipline-level engineers, (2) system engineers, (3) payload/instrument engineers, (4) subsystem lead engineers, (5) project managers, and (6) project scientists.

Jitter Problem Description

- Predicting, managing, controlling, and testing spacecraft line-of-sight (LoS) jitter caused by micro-vibrations from on-board internal disturbance sources is a multidisciplinary engineering task. Especially challenging for missions hosting high-performance vibration-sensitive optical sensor payloads with stringent pointing stability requirements.
- Jitter engineering is a known challenge area. Few practitioners/ SMEs and no established NASA guidelines are available. A key finding from the NESC-sponsored NASA Spacecraft LoS Jitter Workshop was: *There is no generally engineering reference document with guidelines and best practices for managing and mitigating spacecraft jitter.*
- Government and industry would benefit from such jitter guidelines, not only for design purposes, but also for education and insights on analysis and test methods as well as operational considerations.
- The Guidance, Navigation, and Control (GNC) community, as well as other engineering communities typically engaged in solving the jitter problem, need to leverage their collective experiences, and build upon best practices and lessons learned to better address future jitter/micro-vibration challenges.
    - *NASA Technical discipline teams (TDTs) involved:* GNC, Loads and Dynamics (L&D), Mechanical Systems, Structures, Sensors and Instruments, Electro-Mechanical, et al.
- This initiative to create the Jitter Handbook is intended to enable timely knowledge transfer from missions such as James Webb Space Telescope (JWST), Hubble Space Telescope (HST), Roman Space Telescope (RST), Geostationary Operational Environmental Satellites (GOES), Joint Polar Satellite System (JPSS), and more. There is a near-term opportunity (and some degree of urgency) to capture the knowledge of senior jitter SMEs who are nearing retirement or are recently retired.

Multiple Jitter Engineering Challenges

- **A Systems problem <u>with limited experience base</u>**: Jitter is a multidisciplinary effort (Systems, Optics, L&D, Mechanical Systems, GNC, and more) crossing multiple spacecraft subsystems with limited set of practitioners across NASA.
- **Requirements definition**: Observatory level requirements flowed down to lower levels of assembly, budgets/allocations/performance metrics/margins; project WBC/contracts don't necessarily match the physics of the problem.
- Disturbance requirements and modeling: Time or frequency domain. Application point (source) vs. measured at interface. Usually, cannot get transfer function matrix from operational tests.
- Wide Finite Element Model (FEM) frequency range (0.1-500 Hz) and model correlation.
- Requires combination of time and frequency domain analysis results.
- Verification testing challenges: Testing limitations such that typically jitter is a Test-As-You-Fly exception. Expensive and time consuming to perform full-up system-level dynamic interaction testing - only as "flight-like" as feasible in Earth's 1-g environment. System-level verification typically done by analysis. Managing the test and analysis interplay and adapting to the timeline of available information/data.-
- Background noise on testing interferes with disturbance source characterization and creates challenges for dynamic interaction test. Often a signal-to-noise problem.

Jitter Workshop October 2019

To identify lessons learned and best practices, the NESC sponsored a 2-day Spacecraft LoS Jitter Workshop in late 2019. The workshop's goal was to provide a multidisciplinary forum to elicit deeper understanding of issues related to addressing the spacecraft LoS jitter/micro-vibration problem. The primary workshop objective was to identify and share best practices, rules of thumb, and options for jitter-related activities. Representatives from NASA and European Space Agency (ESA), along with NASA's industrial partners, independent consultant SMEs, and members of academia participated.

Jitter is a Systems Problem

- Managing jitter is a highly multidisciplinary systems-oriented task, requiring involvement of an experienced multidisciplinary team, particularly for more demanding spacecraft jitter requirements (e.g., at the nano-radian or pico-radian level).
- This drives the need to create and maintain an experienced, multidisciplinary team to manage jitter throughout the project lifecycle. This should include subject matter experts in both spacecraft and instrument design as well as science and ground system team members responsible for the post-processing of instrument data.
- Jitter management/mitigation- including integrated modelling/simulation and test planning- should be addressed in the early project phases when many impactful system architectural decisions are most often made.
- Excessive conservatism in the design and requirements definition process should be avoided. Margin should be assessed and held at the system level to avoid too many layers of margin across component providers.

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SPACECRAFT LINE-of-SIGHT JITTER MANAGEMENT and MITIGATION LESSONS LEARNED and ENGINEERING BEST PRACTICES

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ABSTRACT

Predicting, managing, controlling, and testing spacecraft line-of-sight (LoS) jitter caused by micro-vibrations due to on-board internal disturbance sources is a formidable multidisciplinary engineering task. It is especially challenging for those missions hosting high-performance (e.g., nano-radian/milli-arcsecond class), vibration-sensitive optical sensor payloads with stringent pointing stability requirements. The Nation Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) are planning technically aggressive spaceflight missions that include ultra-high-performance optical payloads with delicate, highly vibration-sensitive scientific and observational instruments. The guidance, navigation, and control community of practice will need to leverage collective experiences and document their best practices and lessons learned to address future micro-vibration challenges. To identify lessons learned and best practices the NASA Engineering & Safety Center (NESC) sponsored a 2-day Spacecraft LoS Jitter Workshop in late 2019. The workshop's goal was to provide a multidisciplinary forum to elicit deeper understanding of the issues related to addressing the spacecraft LoS jitter/micro-vibration problem. The primary objective was to identify, document, and share lessons learned, best practices, and preferred options for jitter-related analysis and test activities. Representatives from NASA, ESA, along with NASA's industrial partners, independent consultant subject matter experts, and members of academia participated in the workshop. This paper describes the motivation for the workshop and summarize the identified findings and recommendations.

1 INTRODUCTION

In the process of formulating their next generation of Space and Earth flagship-class science missions, the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) intend to push technology and engineering towards higher performing payloads and instruments. This trend towards more capable systems will undoubtedly drive guidance, navigation and control (GN&C) engineers to accommodate and operate payload instruments with increased detector resolution and sensitivity, and longer observational dwell times, leading to more stringent nano-radian/milli-arcsecond class requirements for pointing stability or jitter.

It is generally the case that for instruments performing precise imaging of celestial targets or the remote sensing of the Earth's surface, jitter is the driving requirement for high-quality imaging [1]. In this paper, the term "jitter" refers to uncommanded loss-of-sight (LoS) motion—primarily at

ESA GNC 2021 – C. Dennehy 1

Key Recommendation for NESC-sponsored NASA Spacecraft LoS Jitter Workshop

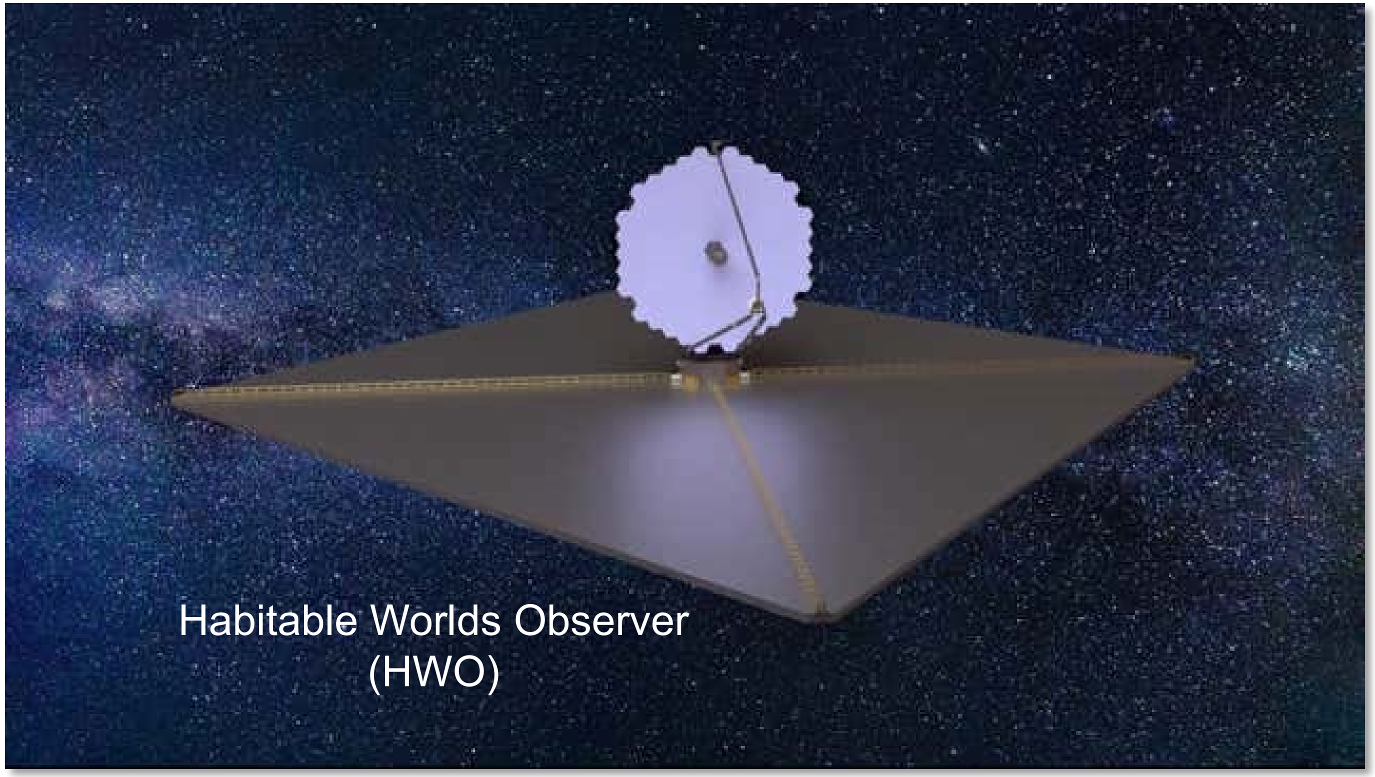
NASA should initiate the development of a Jitter Engineering Guidelines handbook documenting lessons learned and best practices for managing and mitigating spacecraft jitter. This handbook is envisioned as a resource for jitter engineering practitioners, to aid in facilitating consistent technical communication around the subject of jitter, with three target audiences in mind:

1. Early-to-mid career engineers
2. System engineers/lead engineers
3. Project managers

There currently is no NASA standard or handbook on jitter. There is, however, an European Space Agency, European Cooperation for Space Standardization (ESA ECSS) Handbook that addresses spacecraft "Micro-Vibrations".

Question: Is there a USG Jitter Handbook, either unclassified or classified, already in existence? .

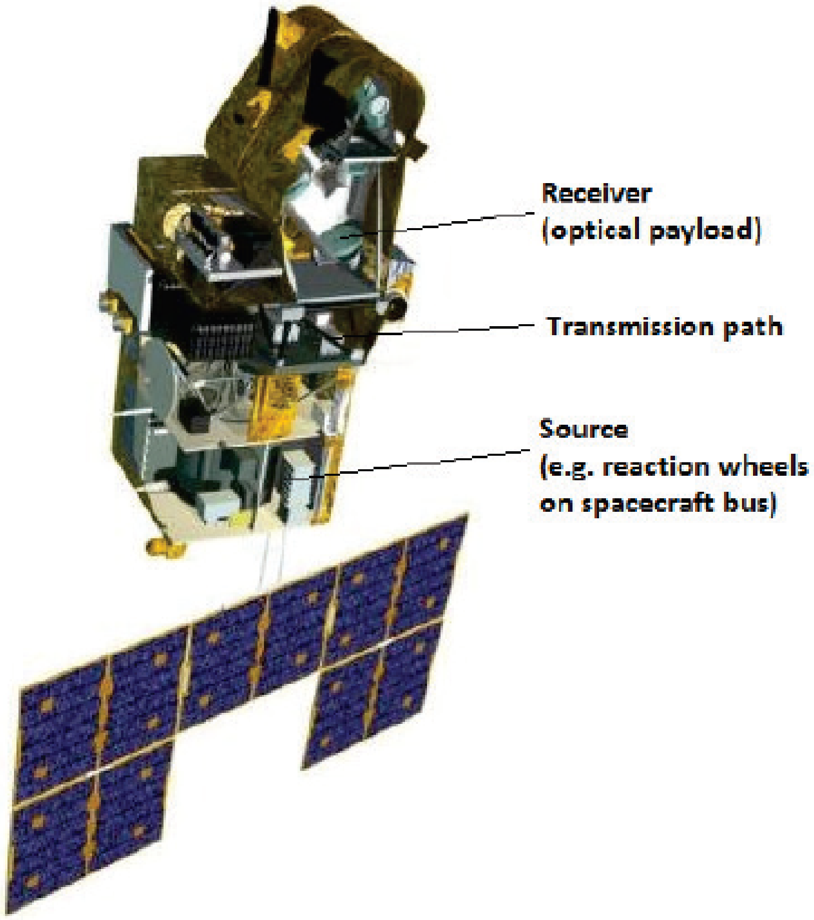
HWO: A Future SMD Mission with Stringent Jitter Requirements

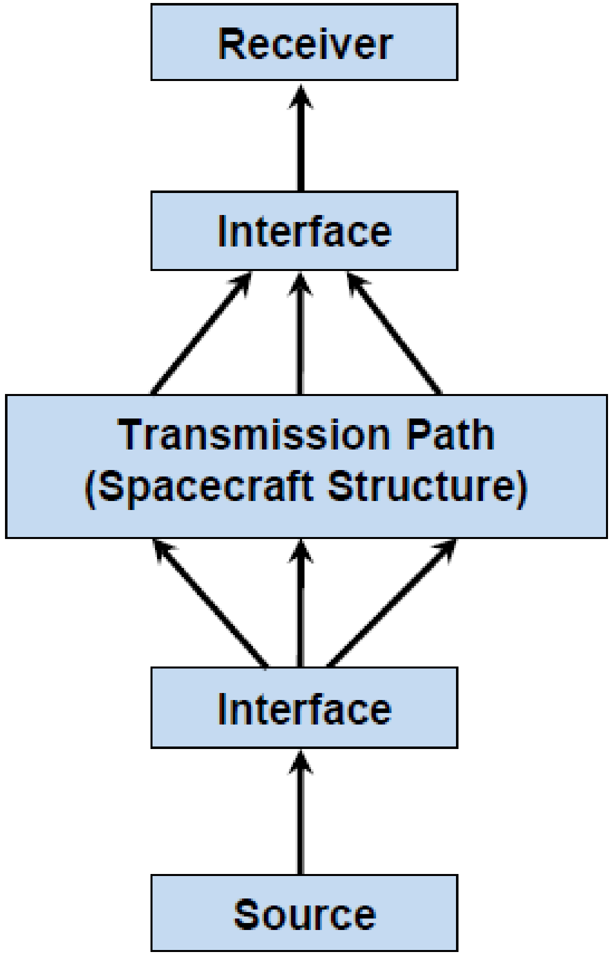


0.1- 0.5 milli-arcsec RMS jitter requirement

Habitable Worlds Observatory (HWO) is a concept for a mission that would search for and characterize habitable planets beyond our solar system. Building upon studies conducted for two earlier mission concepts called the Large Ultraviolet Optical Infrared Surveyor (LUVOIR) and Habitable Exoplanets Observatory (HabEx), HWO would be designed specifically to identify potentially habitable planets around other stars, closely examining their atmospheres to determine if life could possibly exist. Three trades ongoing currently.

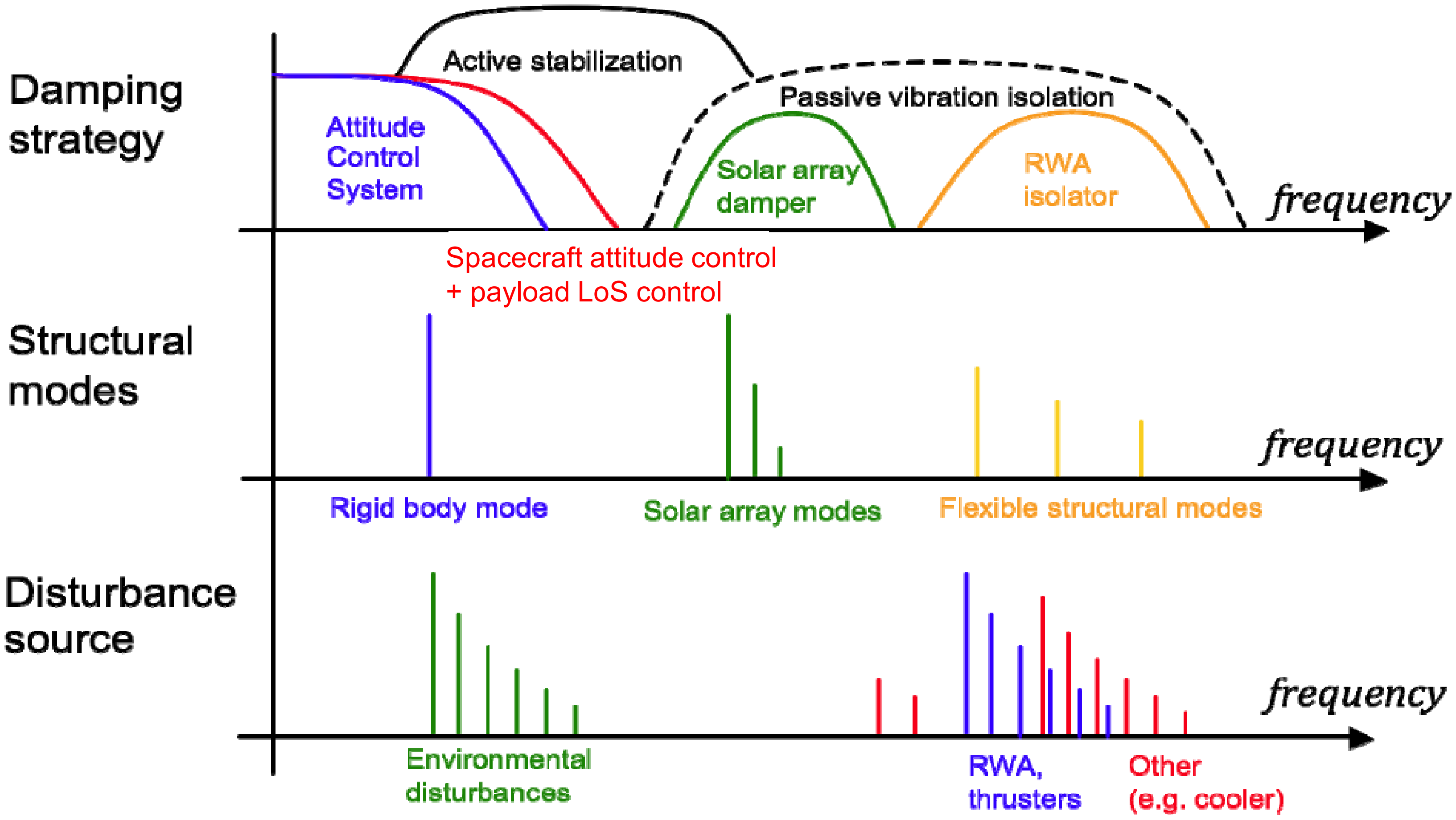
Jitter Causing Disturbance Transmission Through Spacecraft Structure



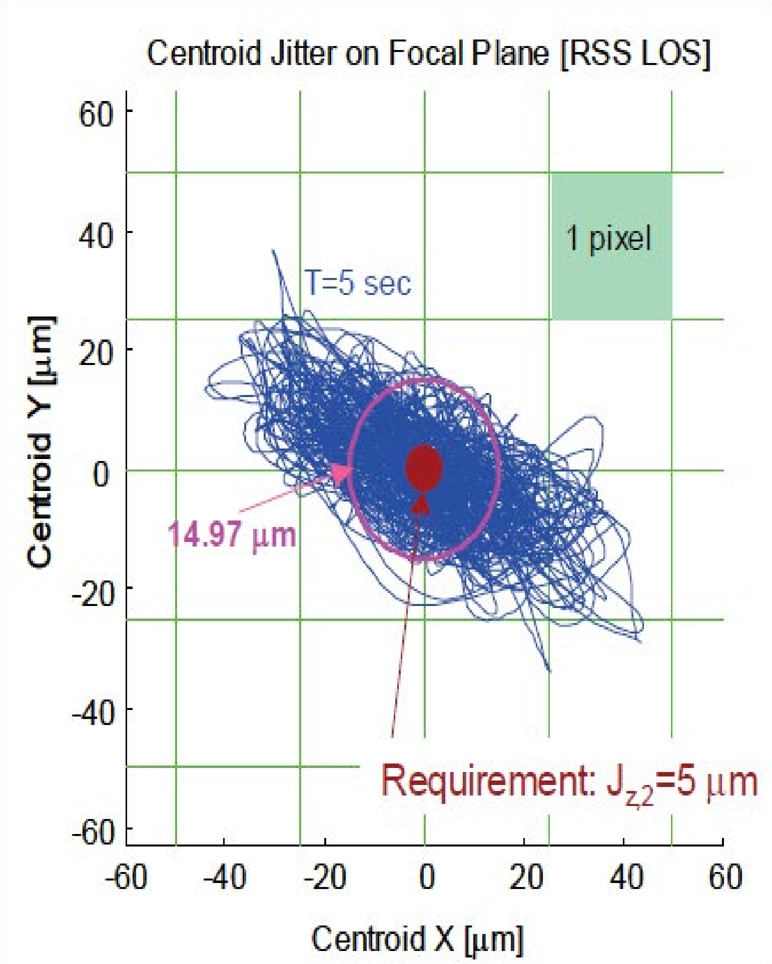


Notional Frequency Spectrum of Spacecraft Disturbances (bottom), Rigid and Flexible Body Structural Modes (middle), and Potential Vibration Damping Approaches (top)

Typically, sinusoidal disturbances with harmonic content couple with lightly damped spacecraft flexible body dynamics. It is challenging to predict the exact nature of the disturbances and the flexible body modal properties. The process typically involves managing uncertainty in the models, with techniques such as the application of Model Uncertainty Factors (MUFs).



Example LoS Pointing Errors and Resulting Effects on Image Quality



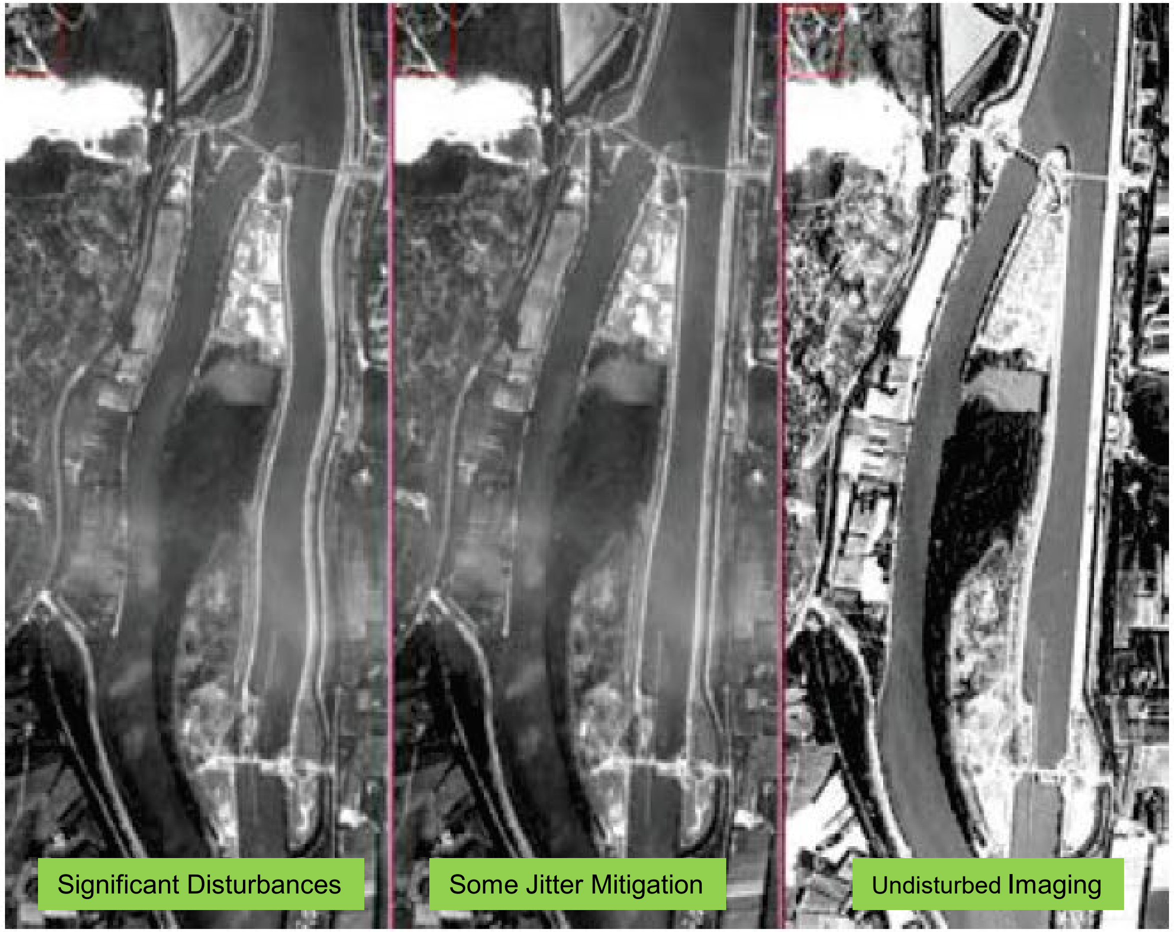


Image extracted from the European Space Agency, European Cooperation for Space Standardization (ESA ECSS) (2012), Section 13.3 Micro-vibrations, Space Engineering: Spacecraft Mechanical Loads Analysis Handbook, ECSS-E-HB-32-26.

Qualitative Assessment of Difficulty of Meeting Jitter Requirements

NASA needs to be prepared to understand and handle technically aggressive spaceflight missions that include highly vibration-sensitive/ultra-high performance optical payloads/observational instruments.

Missions	Jitter Requirement	Importance of Considering Jitter "Up Front"	Mission class
	milliradians	Not considered a challenging requirement	"Typical" Missions
JPSS ***GOES***	microradians (arcsec*)	Important consideration in spacecraft design and architecture	"Typical" Missions
HST ***JWST*** ***RST***	nanoradians (milli-arcsec)	Design driver; needs to be addressed "top to bottom" in system architecture & design, analysis plans, and test plans	*Large Space Telescopes & Optical Communications Terminals*
HWO	picroradians (µarcsec)	Beyond current state of the practice; entails significant challenges and risks in system architecture & design, analysis, and testing	*Future SMD Flagship Missions*

An example of providing qualitative jitter management recommendations to mission designers early in the mission development cycle when they know only LoS requirements. Our jitter handbook working group will compile lessons learned from extensive past experience to provide the supporting rationale for such recommendations.

* 1 arc-second = ~5 micro-radian

Missions
JPSS: Joint Polar Sat System
GOES: Geostationary Ops Env Sat
HST: Hubble Space Telescope
JWST: James Webb Space Tel
RST: Roman Space Telescope
HWO: Habitable Worlds Observer

Quantitative Assessment of Difficulty of Meeting Jitter Requirements

The trend in astrophysics observatory missions is toward tighter and more demanding requirements for pointing stability and jitter mitigation/management.

Consider this space observatory performance benchmark:

Hubble Space Telescope
7 milli-arcsec necessitated extensive, complex system engineering effort!

- Optical telescope assembly mechanically isolated from outer body with wheels and other devices causing disturbances.
- All active components individually tested and modified to suppress potential vibration sources.
- System-level test: spacecraft suspended from isolating air bag and all active components exercised.

Case	Stability/ Accuracy/ Reconstruction (arc-seconds, 1-σ)	Keys/Drivers to Micro-Vibration Design					
		Architecture	Model/ Simulation	ACS	Structural	Instrument Control	Testing
1	100 ++	ACS	Low Fidelity	HW	Low Freq modal	Functional	Interfaces @ I&T
2	10 → 100	Thermal & ACS	Low Freq & Fidelity	HW, CSI	Mid Freq Modal	Functional	Subsystem V&V @ I&T
3	0.1 → 10	Thermal, ACS & Jitter	Med. Freq & Fidelity, @ PDR	HW, CSI	Mid Freq Modal + Asymptotes	Functional + Compensation	Subsystem V&V @ I&T
4	0.01 → 0.1	Thermal, ACS & Jitter	High Freq & Fidelity @ PDR	HW, CSI Operational	High Freq Modal + Asymptotes	Functional + Compensation	Subsystem @ I&T, Component @ CDR
5	$1e^{-3} \rightarrow 1e^{-2}$	Calibration Thermal, ACS & Jitter	High Freq & Fidelity @ SRR	HW, CSI, Operational, algorithms	High Freq Modal + Tailoring	Functional + distributed Control	System @ I&T, Subsystem @ CDR
6	$1e^{-4} \rightarrow 1e^{-3}$	Calibration Thermal, ACS & Jitter	High Freq & Fidelity @ SRR	HW, CSI Operational, algorithms	High Freq Modal + Tailoring	Functional + distributed Control	System @ I&T, Subsystem @ CDR

Known Designs | Drives System | State of the Art | Beyond State of the art → Risk

Source: Oscar Alvarez-Salazar (JPL)

Envisioned Handbook Framework (Preliminary)

What is jitter?
- definition
- cause and effect
- jitter and pointing (jitter is only part of the overall pointing budget)

When does jitter matter?
- mission types and performance requirements
- architectures
- can be a complex and expensive design/test/analysis endeavor

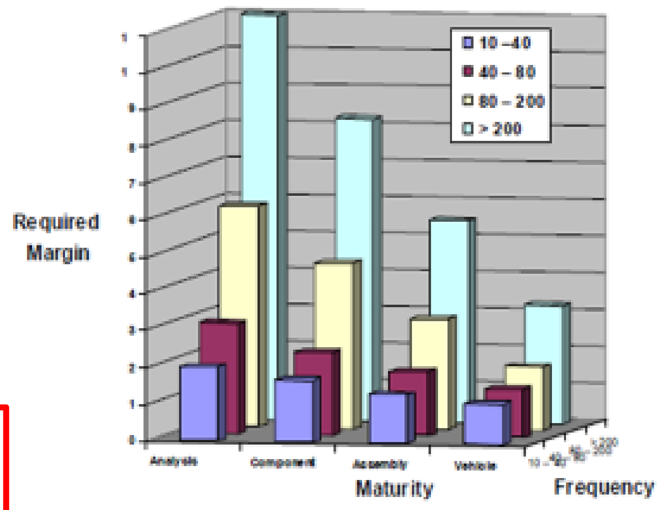
What are approaches to mitigate?
- reduce disturbance at source
  - balance rotating mechanisms (wheels)
  - randomize mechanism operation
  - isolation
  - operational constraints
- reduce susceptibility to disturbance
  - on-board disturbance correction
    - based on motion measurement
    - based on LoS performance
  - post processing disturbance correction
  - isolation
  - operational avoidance/sequencing

- Deliverable: Version 1.0 of the Jitter Handbook will be delivered in April 2026, including mission case studies as Appendices.
- Future work*:* Subsequent updates and additions to Version 1.0 of the handbook will be conducted by the NESC Technical Discipline Teams (TDTs) as necessary.

One Example: MUFs Are A Key Topic to Be Addressed in the Jitter Handbook

Modeling Uncertainty Factors (MUFs)

- MUFs add conservatism to pre-launch predictions of jitter performance, typically before the flight system hardware is developed, assembled, integrated and tested on the ground.
- MUFs capture uncertainties in the structural models, disturbance forcing functions, and other areas of potential dynamic interaction.
- A policy for defining and enforcing MUFs should be defined early in a program
- There is no standard industry-accepted way of defining and "burning down" MUFs during the design and test process. The Jitter Engineering Guidelines Handbook should provide guidance and recommendations for MUF application.



An example set of MUFs as a function of model maturity and frequency [15].

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The definition and recommended application of MUFs is just one example of the type of guideline that would be included in the Jitter Handbook.

Key NASA Stakeholders

- Science Mission Directorate (SMD) — Astrophysics and Earth Science
- Habitable Worlds Observatory (HWO) mission team
- Science Mission Directorate (SMD) Chief Engineer (CE)
- GSFC Flight Projects and Engineering
- Jet Propulsion Laboratory (JPL) Flight Projects and Engineering
- JPL and GSFC Center CEs
- GSFC and JPL science communities

Beyond these NASA stakeholders we envision our industry partners and other government agencies would share a common interest in such a Jitter Handbook

Envisioned Jitter Case Studies of Different Mission Performance Classes

1) Solar Dynamics Observatory (SDO)/JPSS: arc-min pointing: simple conservative analysis, select good components, iterate models (with FEM improvement, modal test results, component vendor tests), decide if it's needed to run a simple Dynamic Interaction Test, be prepared with operational flexibilities

2) GOES: quiet components (wheels), architecture which co-locates pointing sensors and instruments on stiff/isolated bench, active disturbance correction

3) JWST: quiet wheels, Fine Guidance Sensor system, fast steering mechanism to correct LoS, operational constraint during science, control systems optimization

4) *We would also like to have a case study examining the accommodation of an Optical Communications Terminal on a spacecraft. For example, a case study capturing the challenges of accommodating the Orion Artemis II Optical Communications System (O2O). <u>Or something similar.</u>*

NESC Jitter Handbook Working Group (JHWG): Organizational Structure

Dr. Chris D'Souza
(NESC Lead)

JHWG Co-Chair	JHWG Co-Chair	JHWG Co-Chair
Dr. Alice Liu *(GNC TDT, GSFC)*	Dr. John Spanos *(JPL)*	Daniel Kaufman *(L&D TDT, GSFC)*

Jitter SMEs from NESC TDTs / programs / projects

Uday Shankar	Erik Stoneking	Sam Sirlin
Marie Levine	Michael Hagopian	Neil Dennehy
James O'Donnell	Mark Pittelkau	Others

Technical Advisory Group (TAG)

Nick Jedrich (SMD CE)
Carmel Conaty (NESC)
Oscar Alvarez-Salazar (JPL)
David Bayard (JPL)
Miguel San Martin (JPL)
Lee Fienberg (HWO)
Tupper Hyde (GSFC CE)
Dexter Johnson (NESC)
Ali Kolaini (NESC)
Michael Dube (NESC)
Taylor Deneen (NESC)
Jon Holladay (NESC)
Upendra Singh (NESC)
Joel Sills (NESC)
Richard Chiang (Aerospace Corp.)

Role of the TAG: A multi-disciplinary group of experienced senior engineers that provides strategic guidance, advice, insights, and technical support to the JHWG during the overall jitter handbook development process. The TAG would not be involved in the day-to-day work creating the Jitter Handbook; it would instead perform periodic reviews of the handbook drafts.

Some Possible Steps Forwards for Collaboration

- Identify some interested Points of Contact from within this community to communicate progress with and share interim results.

- Identify Subject Matter Experts (SMEs) from this community to augment the Technical Advisory Group (TAG) to help review incremental progress/products

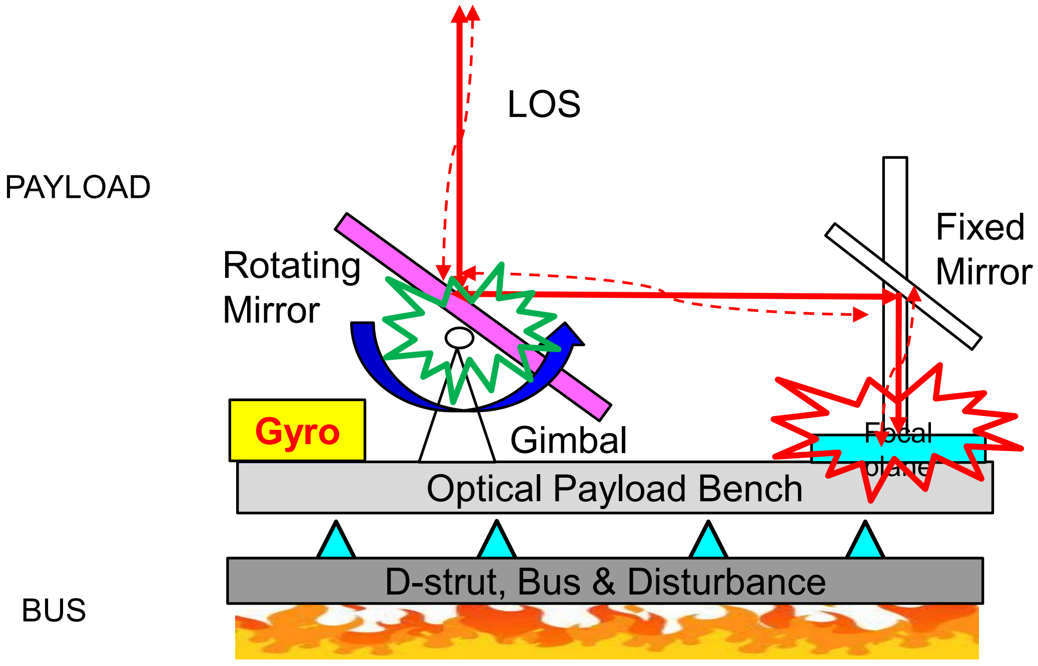
- Development of additional case studies, e.g. the accommodation of an Optical Communications Terminal or a challenging, but unclassified, spacecraft instrument jitter problem

Preliminary Plan for Jitter Handbook Technical Activities

Step	Dates	Activity
1	March 2025	Formally establish NESC Jitter Handbook Working Group (JHWG) and hold kickoff meeting
2	April - May 2025	JHWG to develop detailed Jitter Handbook outline to reflect all multi-disciplinary aspects/perspectives
3	June 2025	Get feedback on outline across all engaged NASA Technical Fellows/TDTs as well as from the SMEs in the Technical Advisory Group (TAG)
4	July – Sept 2025	Sub-teams select and develop specific detailed case studies documenting past space observatory jitter engineering challenges and lessons learned representing different mission performance classes, for example: HST, GOES, JPSS, JWST, RST, SDO, etc. For consistency info from these case studies will be captured using a standard set of questions and specified scope/content.
5	Oct -Nov 2025	JHWG to capture initial round of jitter engineering knowledge and case study lessons learned to create first iteration of Jitter Handbook
6	Dec 2025	Review first iteration of Jitter Handbook and case studies with relevant Technical Fellows/TDTs and TAG SMEs. Identify and prioritize remaining Handbook gaps to be addressed.
7	Jan 2026	JHWG to capture gap-filling jitter engineering knowledge from all engaged SMEs and disciplines to create initial Jitter Handbook.
8	Feb 2026	TAG to review final draft of initial iteration of Jitter Handbook and provide feedback to JHWG
9	Feb - Mar 2026	JHWG does final update to Handbook based upon TAG feedback. TAG to review completed Jitter Handbook.
10	Schedule Margin	There is none
11	April 2026	Submit Handbook for Export Control analysis. Deliver initial version of Jitter Handbook.
12	*Post-delivery*	*Solicit community feedback on initial version of Jitter Handbook.*

But Wait, There's More: NASA's Space Observatory Precision Pointing Benchmark Problem

- **NASA, in close collaboration with The Aerospace Corporation, has formulated a new space observatory benchmark problem focused on the challenging aspects of optical payload Line-of-Sight (LOS) precision pointing.**
- **New benchmark problem provides common framework for researchers to investigate various advanced control techniques that the aerospace industrial community has been hesitant to employ due to a perception of higher risk and/or unfamiliarity.**
- **Benchmark problem could have a significant influence on the field by providing an opportunity for users to experiment with solutions based on neural networks, H_∞, adaptive methods, machine learning, model predictive control, on-line convex optimization, and other modern, novel, and evolving techniques. A complete solution will include verification methodology.**
- **Academic researchers are familiar with these advanced control techniques, unfortunately many do not have access to recognized high-fidelity benchmark problems.**
- **This benchmark problem therefore can serve as a bridge between the academic and industrial communities.**
- ***Currently in process of obtaining approval for public release of this benchmark problem from the NASA Software Release System (SRS).***



This new benchmark is intended to facilitate infusion of new control approaches (along with their V&V methods) from the academic R&D world to the industrial production environment.

"This really is an innovative approach, but I'm afraid we can't consider it. It's never been done before."

THANKS FOR YOUR ATTENTION!

We are open to potential collaboration in the creation of this Handbook

We welcome your thoughts on the need for a Jitter Handbook

QUESTIONS or COMMENTS?

Additional Information:

Backup Charts

Jitter Definition

- There are multiple similar, but not identical, definitions of jitter and associated terms in use across the jitter engineering community.
- The answer to “what is jitter?” often depends on who exactly is being asked the question.
  - ➢ This reflects the need to converge on a single set of definitions accepted and understood by the multidisciplinary community to facilitate sharing and reuse of analysis methods, design concepts, and system engineering processes.
- ***Working Definition:*** **Jitter is the motion of the optical beam caused by motion of the optics due to mechanical disturbances from reaction wheels, stepper motor actuators, cryocoolers, and other mechanisms. Jitter is usually considered medium to high frequency in nature, and often periodic. It is sometimes defined as any pointing error beyond the control bandwidth of the spacecraft’s attitude control system (ACS).**

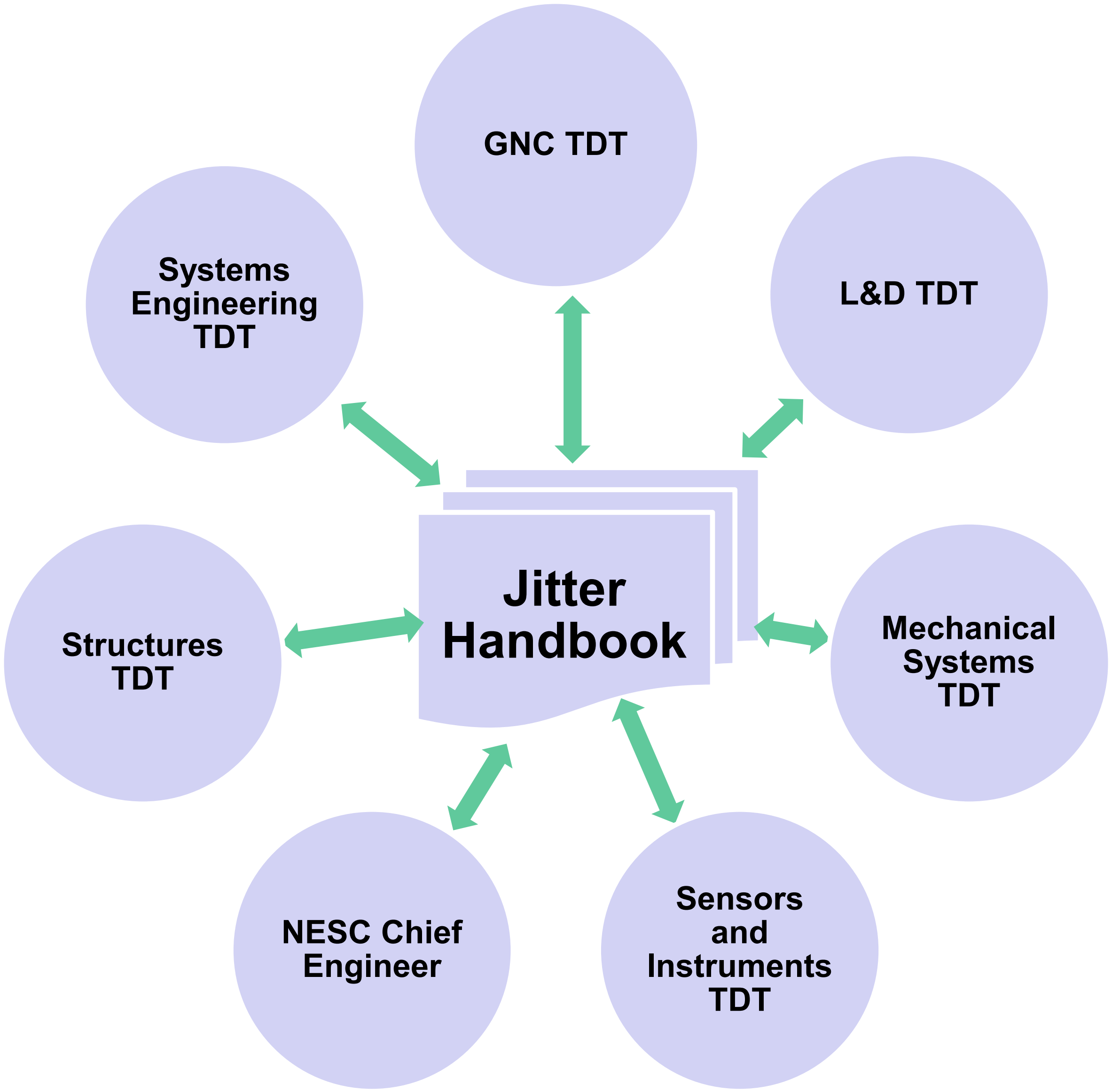
One of the primary goals of this initiative is to **converge** on common jitter terminology, across the multiple disciplines involved and documented in the Jitter handbook.

More Jitter Design, Analysis, and Test Complexities

Jitter crosses subsystems (ACS, instrument, electromechanical/mechanisms, mechanical)

- Jitter and pointing involve control systems
- Non-colocation of sensors and correction systems
- Conflicting requirements of stiffness and isolation
- Prosecuting a verification and validation program
    - -Timeline of available information/data
    - -Test and analysis interplay
    - -Testing limitations in 1-G environment

Jitter Handbook Team / Technical Contributors



Potential Jitter Mitigations

Combinations of design tools are used to develop the most cost-effective strategies to mitigate jitter concerns

Mechanism	Control Systems	Structural Dynamics	Optics	On-Orbit Operations
Lower disturbance inputs	Compensate low-frequency errors	Reduce dynamic responses	Active optics	Avoid operating mechanisms during observation