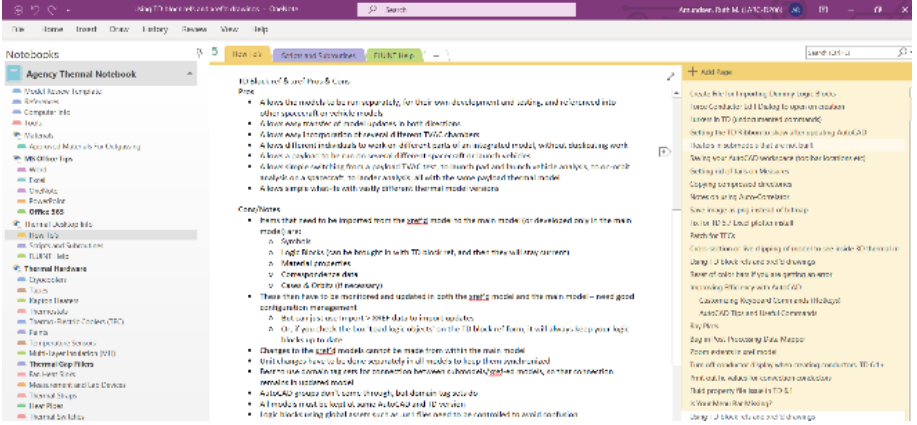


Fostering a Technical Discipline Community

Ruth M. Amundsen

April 10, 2024


National Aeronautics and Space Administration

NASA Passive Thermal Control Engineering Guidebook

Revision: 4.0

Page 1 of 202

Distribution Restriction: Publicly available

Security Classification: Unclassified

NASA Passive Thermal Control Engineering Guidebook

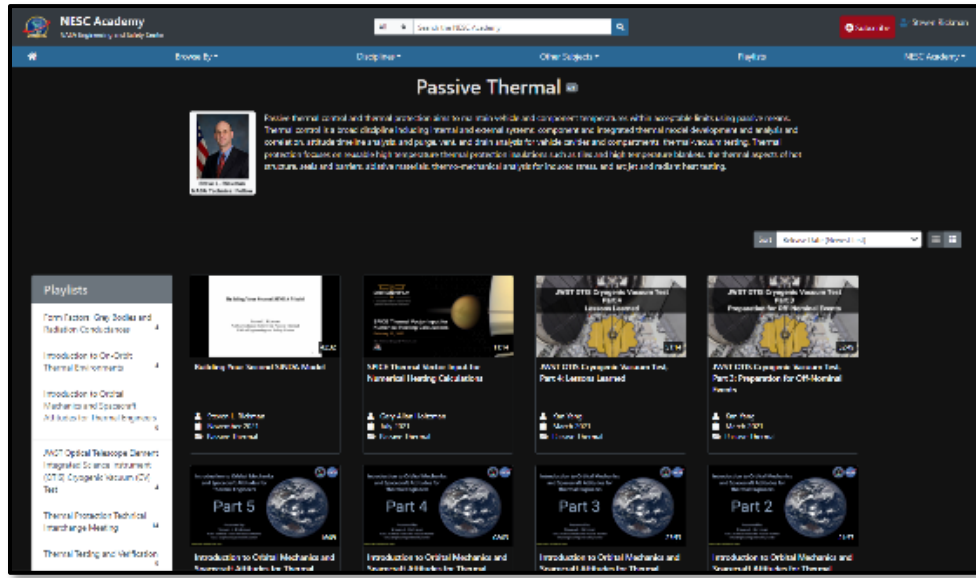
Developed with support from the NASA Engineering and Safety Center (NESC) Passive Thermal Technical Discipline Team (TDT)

Compiled by:

Kaitlin Liles and Ruth Amundsen

Version: 4.0

Date: September 25 2023



Agenda

- Historical background for thermal community
- Benefits of tight-knit discipline community
- Example knowledge sharing methods from thermal
- Expansion to other disciplines

Where This Started

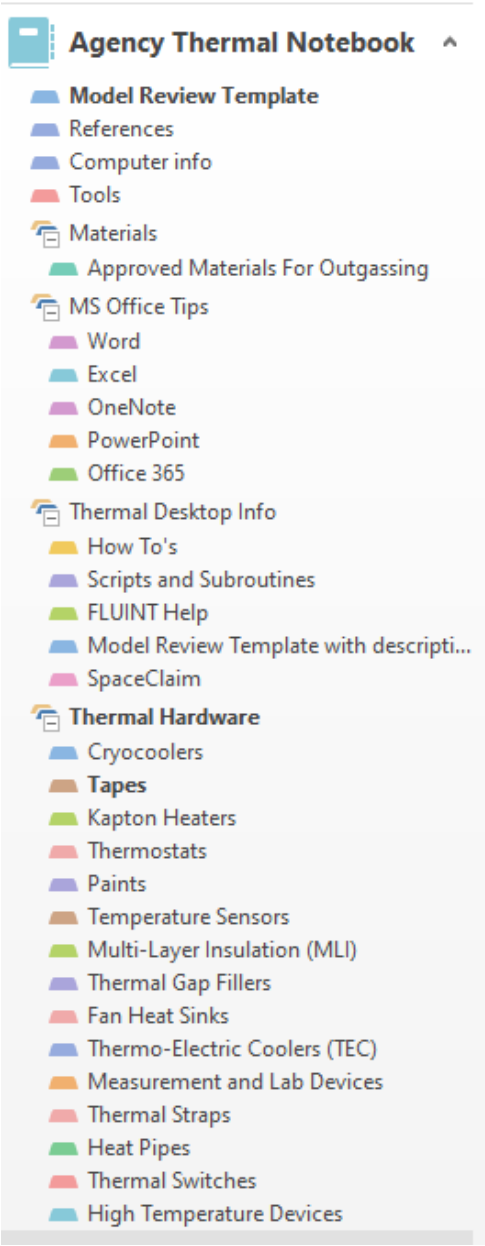
- In 1989, NASA GRC held the first TFAWS – Thermal & Fluids Analysis WorkShop
- All NASA Centers, plus academics & industry
- NASA Delegates meeting for NASA-only discussion
- Uniquely thermal focus
- Informal structure
- Lots of networking time
- Both papers and training

What This Does

- Meeting face to face allows personal acquaintance with engineers at other Centers
- Allows engineers to be comfortable sharing both successes and mistakes
- Removes the fear factor in asking for help
- Informal time allows cross-center networking
- Blend of training for younger engineers, papers/panel sessions for more experienced, and short courses for both
- Knowledge of people at other Centers allows quick outreach
- NASA-only Delegates meeting allows frank discussion

Why Share Knowledge?

- Employees more productive
  - Avoids trouble-shooting problems others have already solved
  - Benefit from other Centers' best practices to improve local practices
  - Share work products: documents, procedures, models, etc.
  - New employees useful more quickly
- Improves morale
- Easier out-sourcing to other Centers for reviews
- Potential to share workload as methods standardize
- Helps thermal discipline nationally, by publicly sharing knowledge gained paid for by US tax dollars

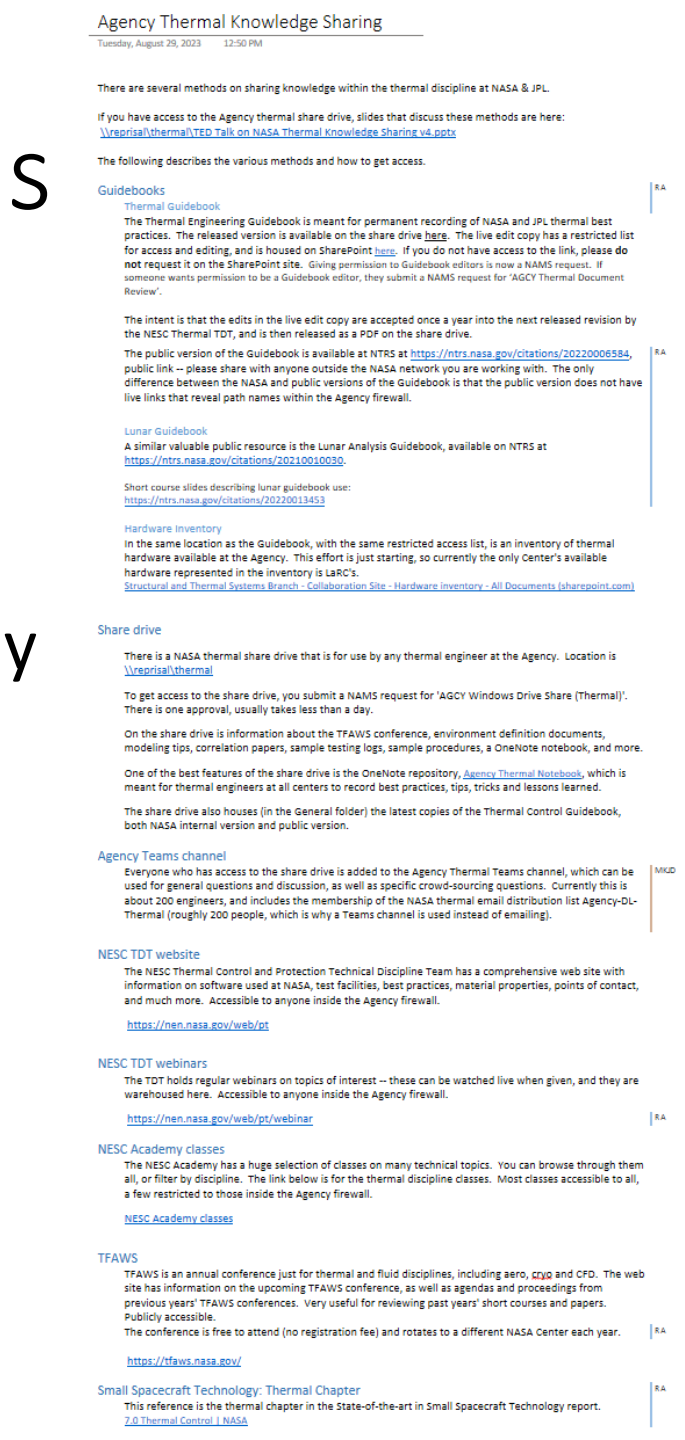


Growth of Sharing Processes

- Annual discussions at TFAWS led to:
  - Coalescence around a single main software package
  - Centralizing purchasing for common tools
  - Panel discussions on common test methods
  - Passing TFAWS hosting responsibility between Centers
  - More understanding of other Centers' work via tours & papers
  - Sharing models and modeling techniques
  - Documenting best practices for thermal discipline
    - Model development
    - Model integration
    - Model configuration control
    - Hardware selection

Current Knowledge Sharing Methods

- Shared drive with OneNote
- Centrally edited Guidebook
- NESC Technical Discipline Team Webinars and Academy classes
- Annual TFAWS papers and short courses
- Agency thermal Teams channel
- Agency shared hardware inventory
- NESC TDT crowd-sourcing emails



Agency Thermal Knowledge Sharing

Tuesday, August 29, 2023 12:50 PM

There are several methods on sharing knowledge within the thermal discipline at NASA & JPL.

If you have access to the Agency thermal share drive, slides that discuss these methods are here:
\\reprisal\thermal\TED Talk on NASA Thermal Knowledge Sharing v4.pptx

The following describes the various methods and how to get access.

Guidebooks

Thermal Guidebook

The Thermal Engineering Guidebook is meant for permanent recording of NASA and JPL thermal best practices. The released version is available on the share drive here. The live edit copy has a restricted list for access and editing, and is housed on SharePoint here. If you do not have access to the link, please do not request it on the SharePoint site. Giving permission to Guidebook editors is now a NAMS request. If someone wants permission to be a Guidebook editor, they submit a NAMS request for 'AGCY Thermal Document Review'.

The intent is that the edits in the live edit copy are accepted once a year into the next released revision by the NESC Thermal TDT, and is then released as a PDF on the share drive.

The public version of the Guidebook is available at NTRS at https://ntrs.nasa.gov/citations/20220006584, public link -- please share with anyone outside the NASA network you are working with. The only difference between the NASA and public versions of the Guidebook is that the public version does not have live links that reveal path names within the Agency firewall.

Lunar Guidebook

A similar valuable public resource is the Lunar Analysis Guidebook, available on NTRS at https://ntrs.nasa.gov/citations/20210010030.

Short course slides describing lunar guidebook use:
https://ntrs.nasa.gov/citations/20220013453

Hardware Inventory

In the same location as the Guidebook, with the same restricted access list, is an inventory of thermal hardware available at the Agency. This effort is just starting, so currently the only Center's available hardware represented in the inventory is LaRC's.
Structural and Thermal Systems Branch - Collaboration Site - Hardware inventory - All Documents (sharepoint.com)

Share drive

There is a NASA thermal share drive that is for use by any thermal engineer at the Agency. Location is \\reprisal\thermal

To get access to the share drive, you submit a NAMS request for 'AGCY Windows Drive Share (Thermal)'. There is one approval, usually takes less than a day.

On the share drive is information about the TFAWS conference, environment definition documents, modeling tips, correlation papers, sample testing logs, sample procedures, a OneNote notebook, and more.

One of the best features of the share drive is the OneNote repository, Agency Thermal Notebook, which is meant for thermal engineers at all centers to record best practices, tips, tricks and lessons learned.

The share drive also houses (in the General folder) the latest copies of the Thermal Control Guidebook, both NASA internal version and public version.

Agency Teams channel

Everyone who has access to the share drive is added to the Agency Thermal Teams channel, which can be used for general questions and discussion, as well as specific crowd-sourcing questions. Currently this is about 200 engineers, and includes the membership of the NASA thermal email distribution list Agency-DL-Thermal (roughly 200 people, which is why a Teams channel is used instead of emailing).

NESC TDT website

The NESC Thermal Control and Protection Technical Discipline Team has a comprehensive web site with information on software used at NASA, test facilities, best practices, material properties, points of contact, and much more. Accessible to anyone inside the Agency firewall.

https://nen.nasa.gov/web/pt

NESC TDT webinars

The TDT holds regular webinars on topics of interest -- these can be watched live when given, and they are warehoused here. Accessible to anyone inside the Agency firewall.

https://nen.nasa.gov/web/pt/webinar

NESC Academy classes

The NESC Academy has a huge selection of classes on many technical topics. You can browse through them all, or filter by discipline. The link below is for the thermal discipline classes. Most classes accessible to all, a few restricted to those inside the Agency firewall.

NESC Academy classes

TFAWS

TFAWS is an annual conference just for thermal and fluid disciplines, including aero, cryo and CFD. The web site has information on the upcoming TFAWS conference, as well as agendas and proceedings from previous years' TFAWS conferences. Very useful for reviewing past years' short courses and papers. Publicly accessible.
The conference is free to attend (no registration fee) and rotates to a different NASA Center each year.

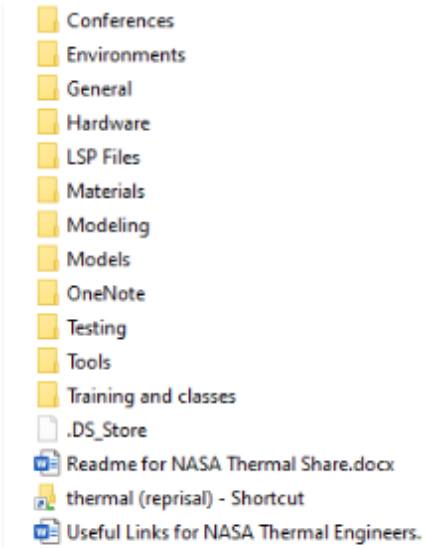
https://tfaws.nasa.gov/

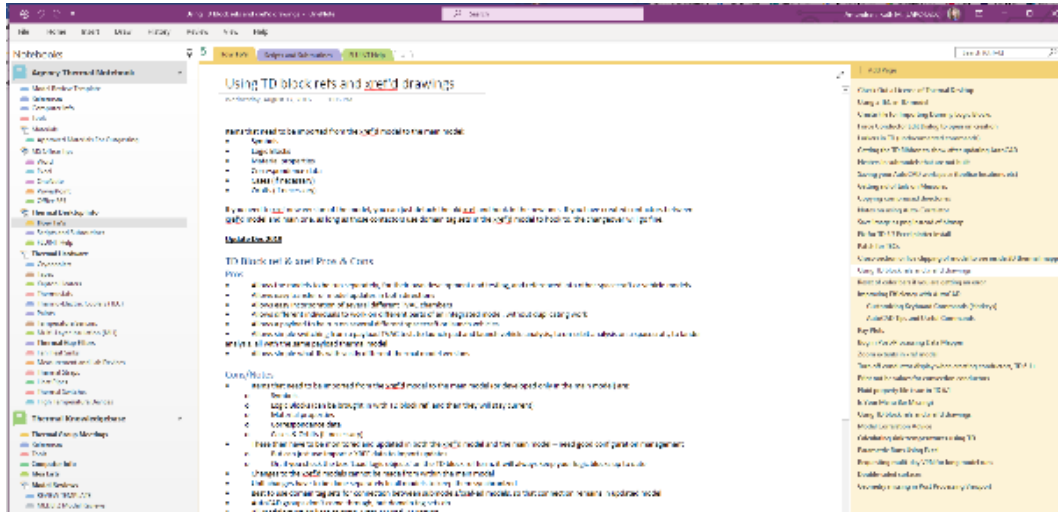
Small Spacecraft Technology: Thermal Chapter

This reference is the thermal chapter in the State-of-the-art in Small Spacecraft Technology report.
7.0 Thermal Control | NASA

NASA Thermal Share Drive & OneNote

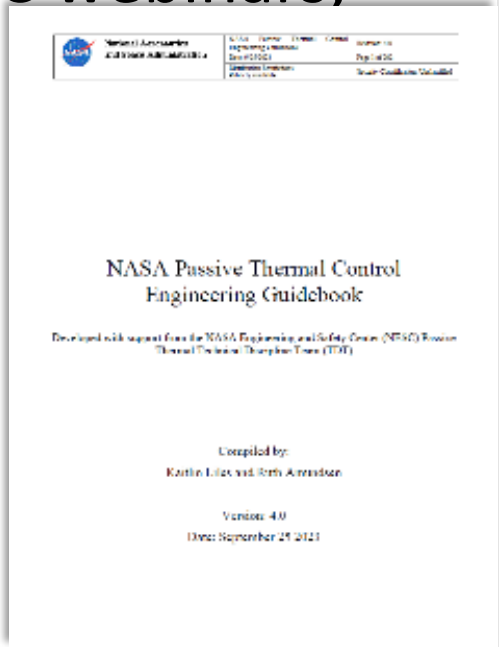
- Leverages Agency-wide breadth of knowledge
- NAMS access request – currently 200 users
- OneNote:
  - Searchable, quick update of best practice by Agency thermal engineers
- Thermal Guidebook links to OneNote
- Resources:
  - Released copies of Thermal & Lunar Guidebooks
  - Slides for new employees
  - Models, tips & tricks
  - Code sections for re-use
  - Sample documents

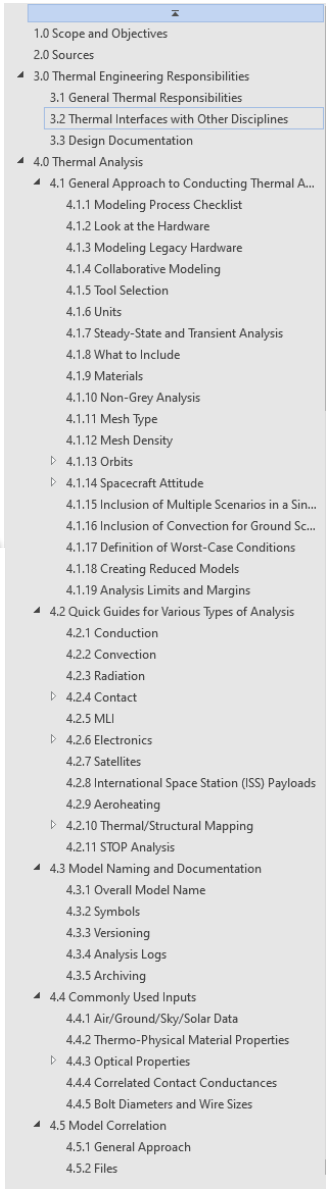




NASA Passive Thermal Engineering Guidebook

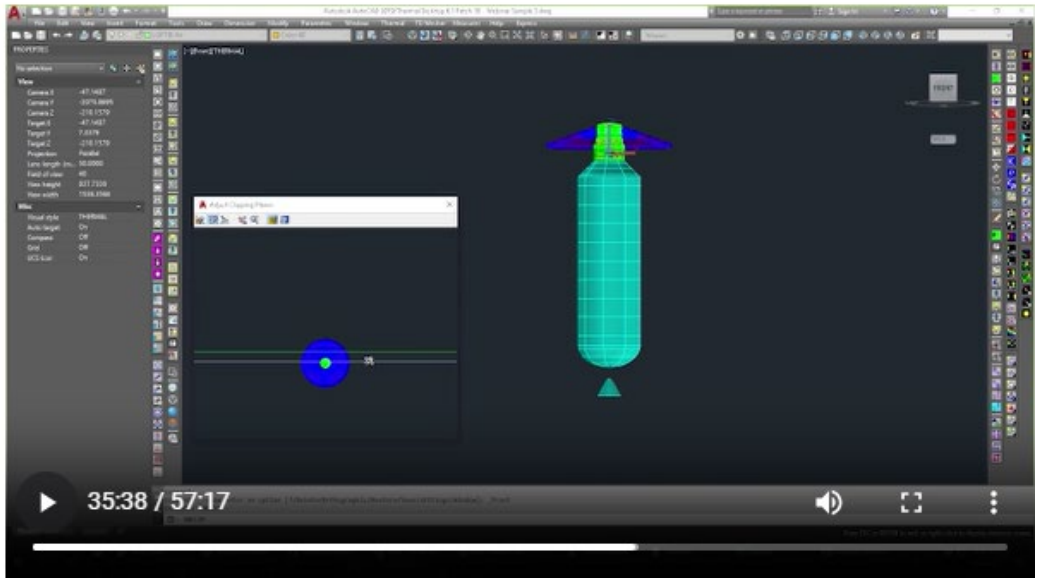
- Leverages Agency-wide knowledge
  - Hosted on SharePoint, currently 200 pages
  - ~80 NASA thermal engineers with edit access
- Edited continually and re-released annually
- Links to share drive OneNote, TFAWS papers, NESC webinars, NESC Academy classes
- Released NASA version on share drive
- Public version shares NASA knowledge across thermal discipline in industry and academia

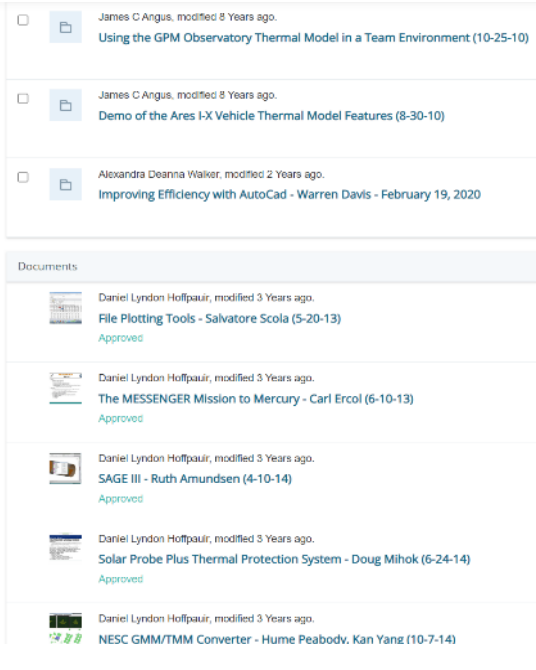




NESC TDT Webinars

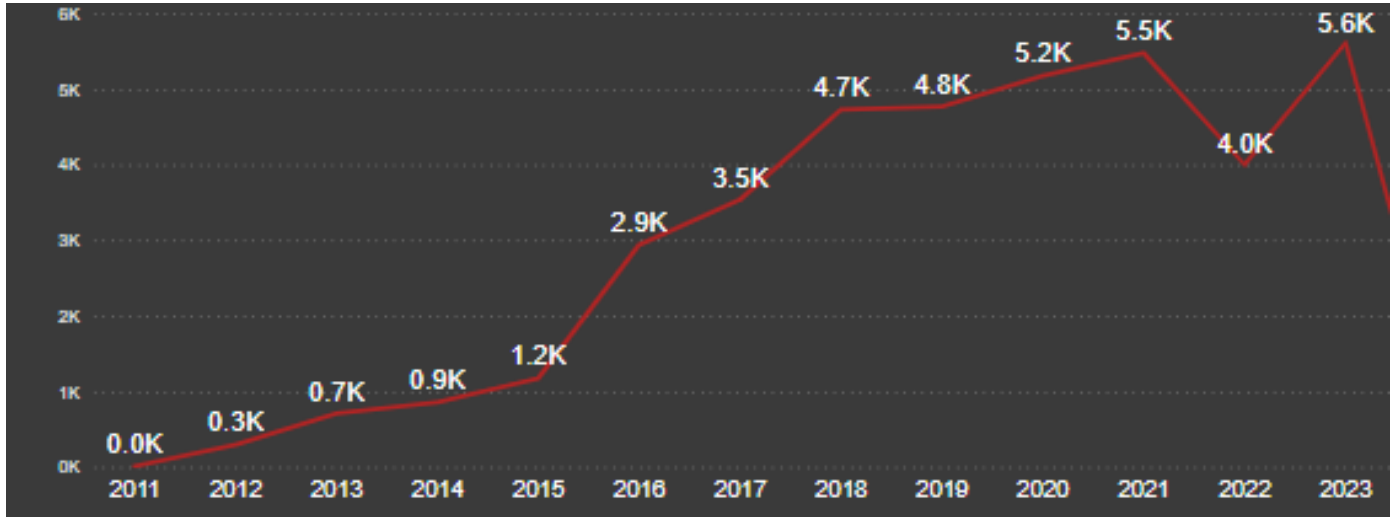
- Great for live demos of modeling techniques with minimal preparation time
- Leverages Agency-wide breadth of knowledge
- Captures current knowledge of those who may leave Agency or transfer to other area

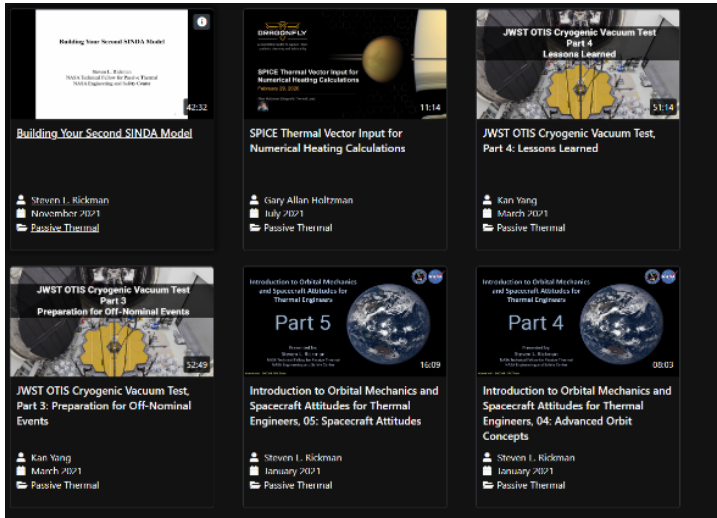




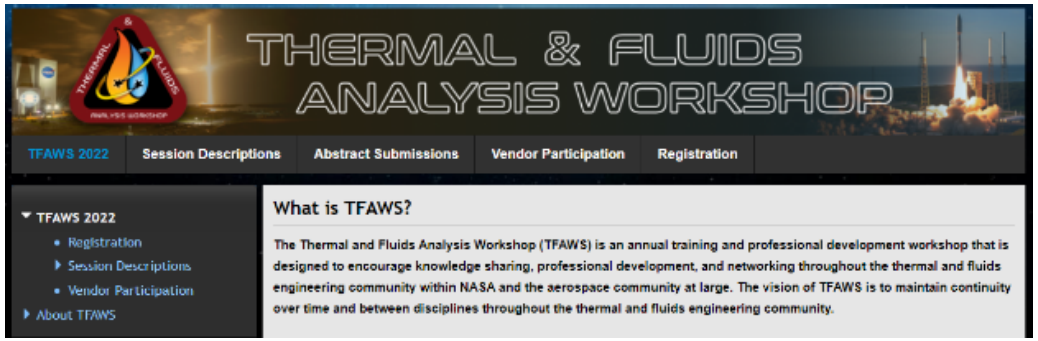
NESC Academy Classes

- Leverages Agency-wide breadth of knowledge
- Great resource for those new to discipline
- Public lessons share NASA thermal knowledge across entire thermal discipline in industry and academia
- Thermal classes ~5000 views/yr, 40K lifetime views





TFAWS Annual Conference

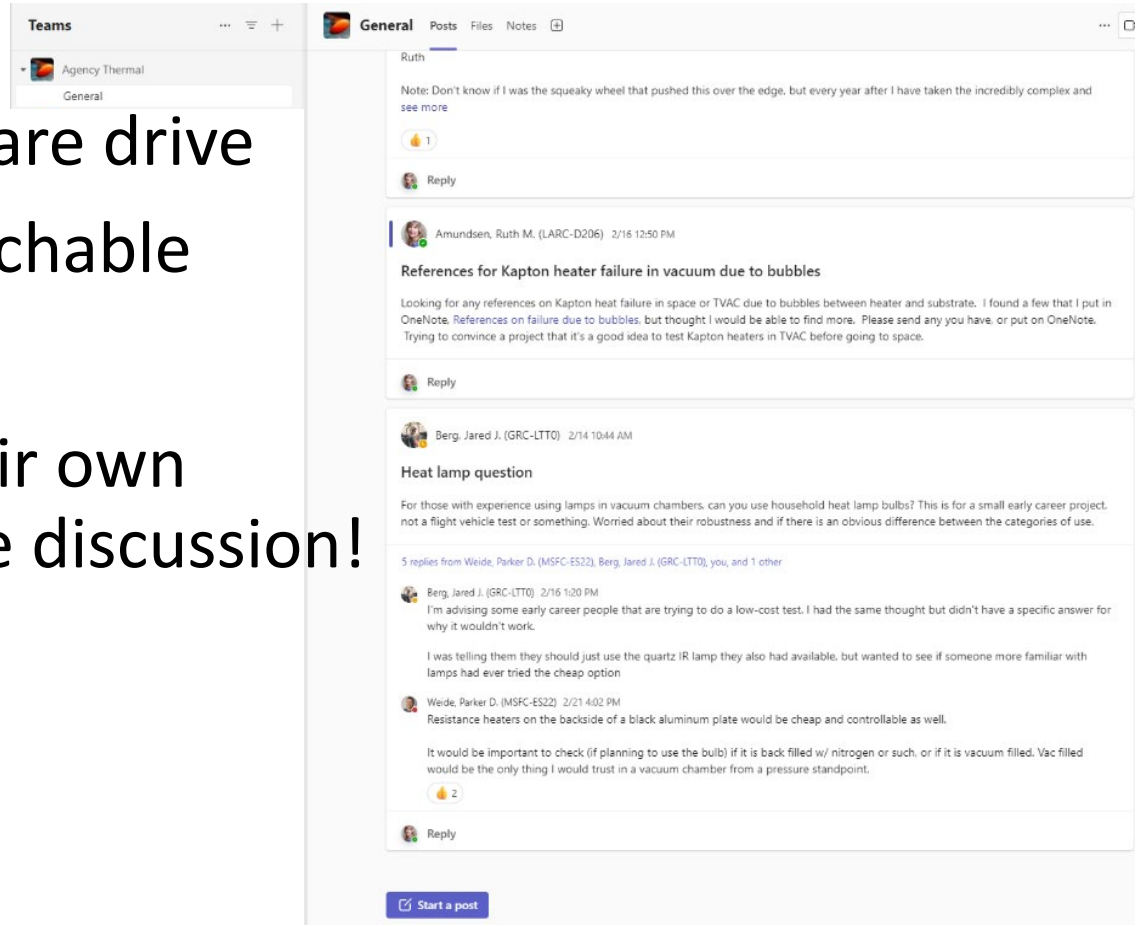


- Long-standing “NASA-owned” Community of Practice (CoP) workshop
- Co-sponsored by NESC Passive Thermal, ECLS, Aerosciences and Cryogenics
- Meet and network with thermal engineers at other Centers and locations
- Papers, short courses, training, social events
- Public papers share NASA thermal knowledge in thermal discipline to industry and academia
- Guidebook links to TFAWS papers
- NASA-only Delegates meeting

Agency Thermal Teams Channel

- Agency thermal Teams channel for whole-discipline Agency discussions
- Same 200 engineer membership as share drive
- Informal discussion, archived and searchable

- Every technical discipline can have their own similar Teams channel for Agency-wide discussion!



Shared Thermal Hardware Inventory

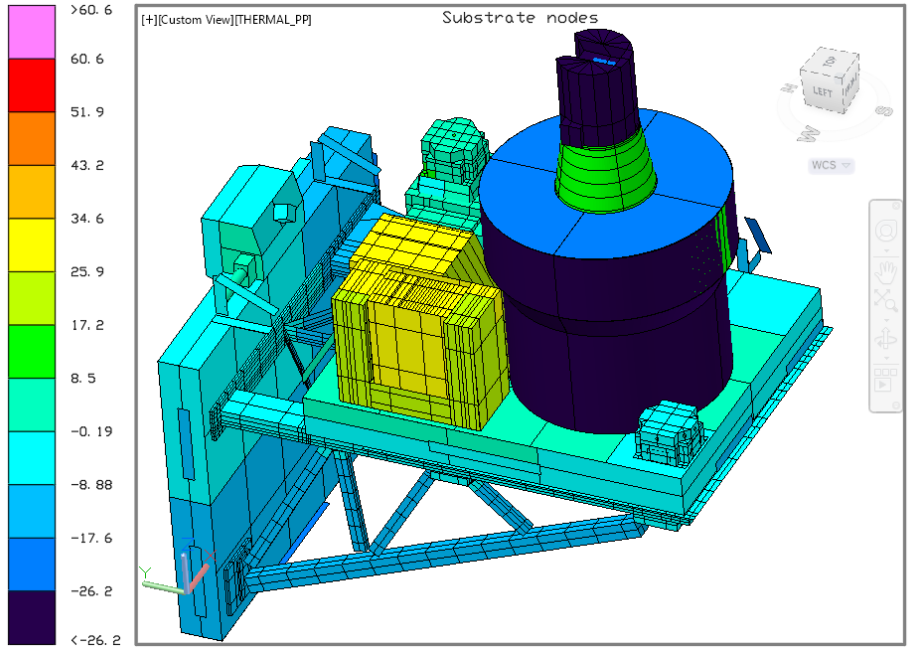
- In 2019, a GSFC program needed flight thermostats
  - LaRC supplied 45 spare thermostats from earlier program
  - Saved GSFC cost and time
- Informal sharing of materials occurs via crowd-sourcing emails to NESC TDT
- Currently starting shared hardware inventory to allow more of this, hosted on SharePoint
- Sample page →

Note that columns in grey text are optional, column in blue text is calcuated. Fill out as much information as you have o
If you request and remove an item, update the 'quantity removed' column -- the 'quantity remaining' column will update
Please enter part number, or specifications (size and resistance), or both
If it is something with an expiration date (such as the adhesive on a heater), please indicate if it is expired in the Notes cc
For Tayco heaters, note that this page has 'TaycoHtr-TPC-6002F-Flex-Page3.pdf' which lets you decode Tayco part numb
onenote:///\\reprisal\thermal\OneNote\Agency%20Thermal%20Notebook\Thermal%20Hardware\Kapton%20Heaters.one#SAGEIII%20Flight%20Heaters&section-id=

Item Type	Description	Part Number	Manufacturer / Vendor	Serial Number
Heater	Wire-Wound	TPC6002-K2-1-51-2.6-4-5-R906-W3-36-1-Q1-120	Tayco	001, 002, 003, 00
Heater	Printed Circuit	TPC6002-K1-1-51-2.6-4.0-5-R567-W6-36-1-Q1-120	Tayco	001 - 003
Heater	Printed Circuit	TPC6002-K1-1-51-4.0-2.6-5-R575-W6-36-1-Q1-120	Tayco	001 - 006
Heater	Printed Circuit	TPC6002-K1-1-51-2.6-4.0-5-R543-W6-36-1-Q1-120	Tayco	001 - 004
Heater	Printed Circuit	TPC6002-K1-1-51-1.3-7.0-5-R514-W6-36-1-Q1-120	Tayco	001 - 006
Heater	Wire-Wound	TPC6002-K2-1-51-1.6-2.8-5-R514-W6-36-1-Q1-120	Tayco	001 - 012
Heater	Wire-Wound	TPC6002-K2-1-51-1.0-2.7-5-R1553-W6-36-1-Q1-120	Tayco	001 - 024
Heater	Wire-Wound	TPC6002-K2-1-51-1.3-7.0-5-R970-W6-36-1-Q1-120	Tayco	001 - 012
Heater	Wire-Wound	TPC6002-K2-3-61-4.5-0-5-R1134-R970-R970-W6-36-1-Q1	Tayco	001 - 009
Heater	Wire-Wound	TPC6002-K2-1-51-1.6-2.8-5-R1026-W6-36-1-Q1-120	Tayco	001 - 006
Heater	Wire-Wound	TPC6002-K2-1-51-1.0-2.7-5-R1294-W6-36-1-Q1-120	Tayco	001 - 006
Heater	Wire-Wound	TPC6002-K2-1-51-1.3-7.0-5-R863-W6-36-1-Q1-120	Tayco	001 - 006
Heater	Wire-Wound	TPC6002-K2-1-51-1.0-2.7-5-R1694-W6-36-1-Q1-120	Tayco	001 - 012
Heater	26 Ohm	112-7338-591		
Heater	181.5 Ohm	112-7338-592		002, 003
Heater	40.05 Ohm	HAP6945	Minco	
Heater	Polyimide Insulated Flexible Heaters		Omega	
Heater	181.5 ohm	112-7338-592	Tayco	002, 003

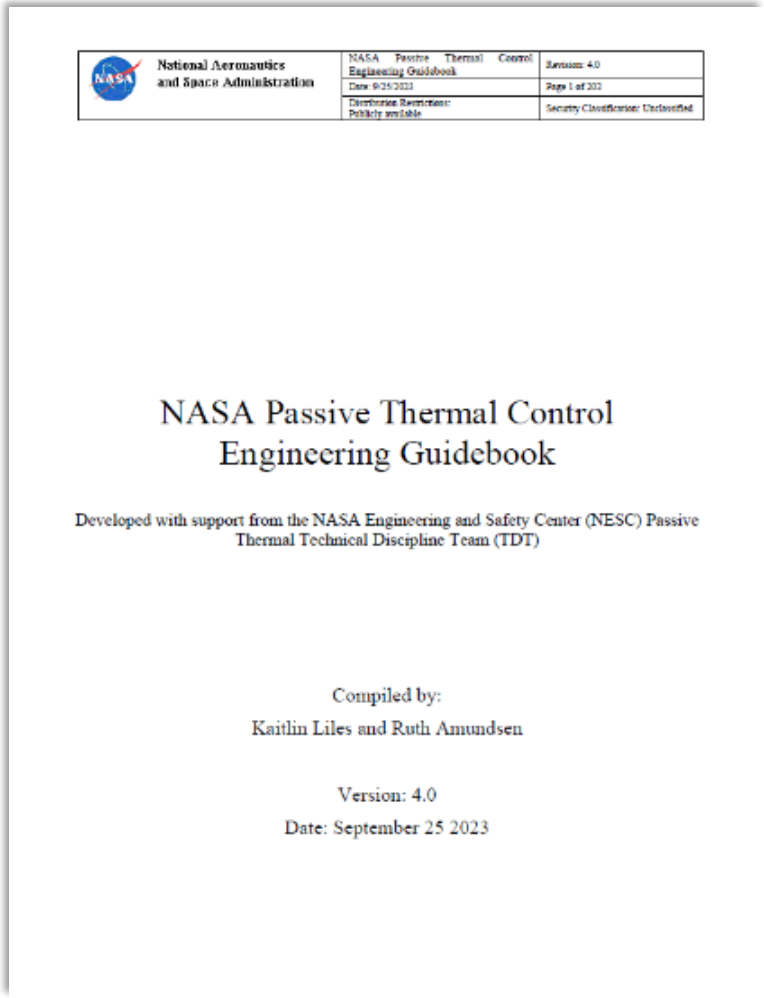
Agency Contract for Software

- Common thermal software package, Thermal Desktop, purchased on centralized Agency contract since 2005
  - Saved time of engineers writing PRs
  - Came about because of agreements reached at TFAWS
- Now moving to sharing licenses on HQ servers
- Common tool and common licensing
  - Saves procurement time
  - Allows sharing lessons learned
  - Allows sharing work



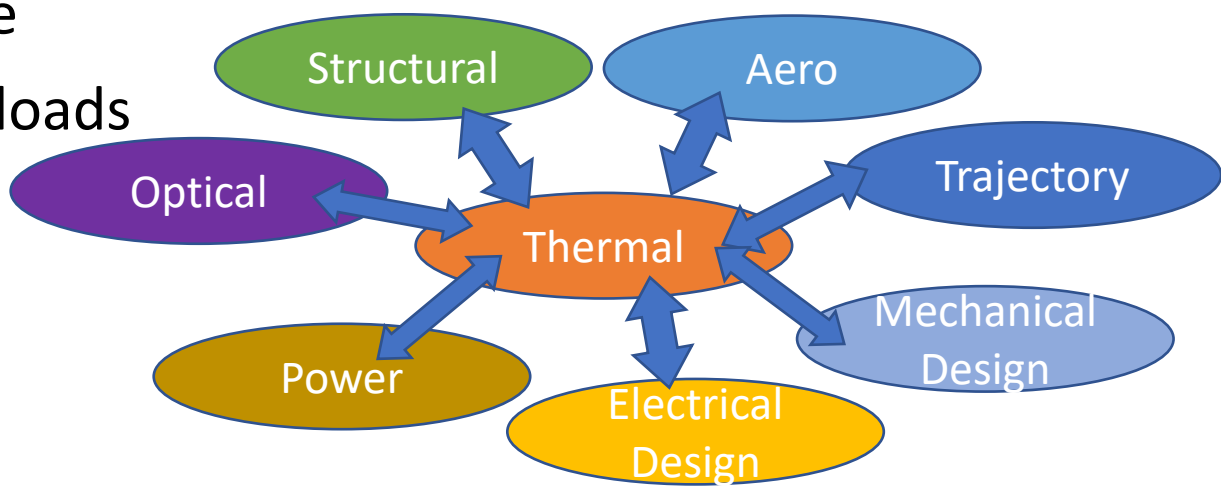
Guidebook Practices

- Having Guidebook to define best practices drives many improvements
  - Model versioning and log
    - Important for interfaces with other disciplines like structural and aero
    - Ideal if all interfacing disciplines used model versioning
  - TVAC log
  - Model integration
  - Software selection
  - Hardware selection



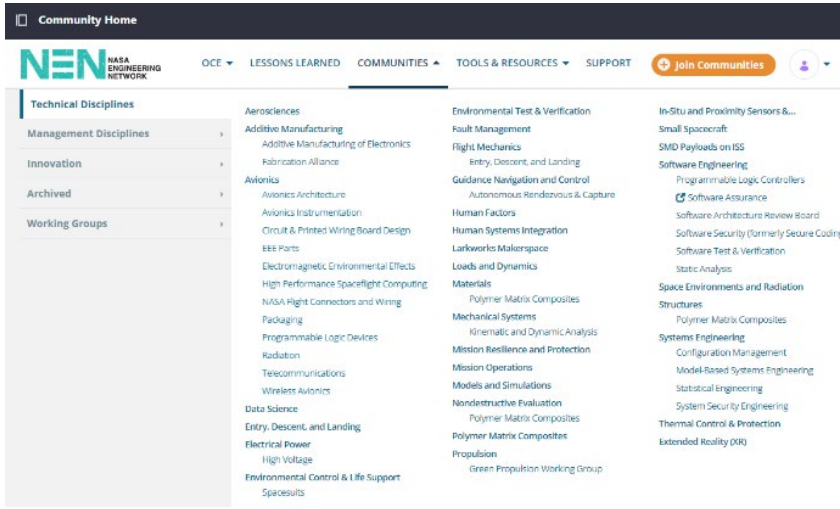
Why Thermal Tends to Network

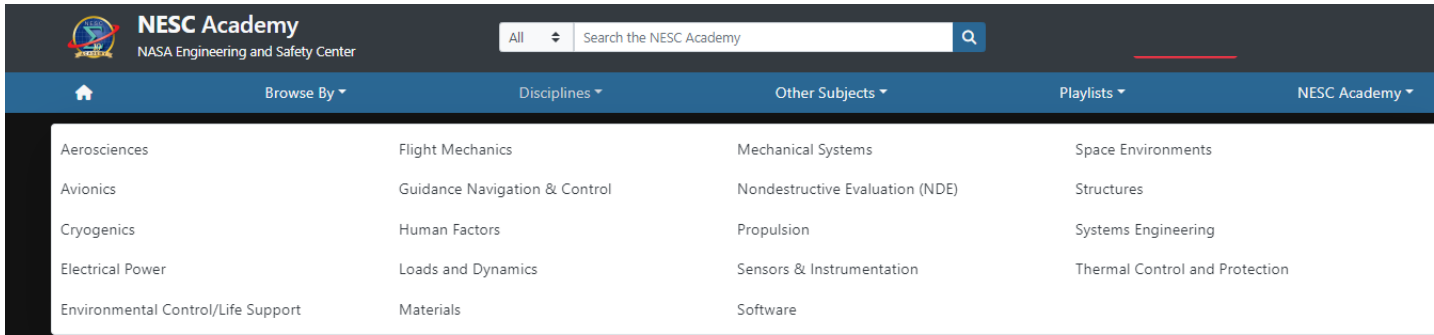
- Many discipline interfaces: structural, mechanical, electrical, power, aeroheating, trajectory, optical, controls
  - Tracking multiple inputs & outputs
- Thermal models often have many engineers working in them simultaneously
  - Forces good communication and log-keeping
- Thermal lead often migrates to systems, forcing good log-keeping as another engineer takes over model
- Thermal persists throughout project lifecycle
- Large scale model like ISS used by many payloads
- Model correlation forces good note-keeping



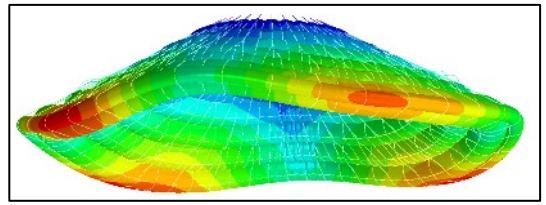
Expansion to Other Disciplines

- Not all disciplines have same inherent networking as thermal
- But can still work to share knowledge the same way
- Ensure all engineers feel empowered to share lessons learned
- Emphasize being good citizen of the community
- Create paths for that sharing:
  - OneNote
  - Guidebook
  - Teams channel
  - Hardware/software inventory
  - NESC Academy classes

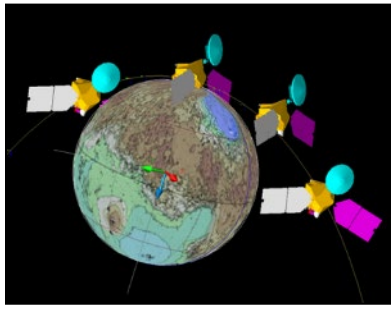


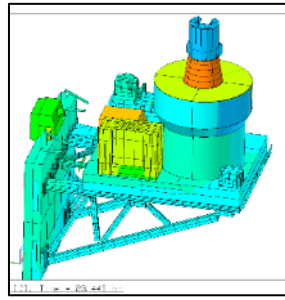


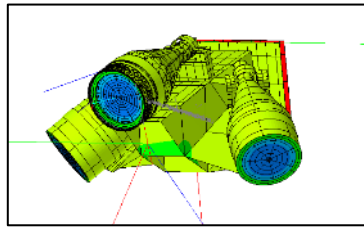
How Does This Sharing Benefit NASA



- Analysts learn from mistakes made by all in the discipline
- All Centers have access to best knowledge and practices
- Less competition between engineers from different Centers
- More cooperation between Centers
- Shares info on methods and materials saves time
- Sharing spare hardware saves time and money
- All engineers feel like good citizens of their technical community







Methods to Improve Networking

- Support ways of building trust between Centers in your discipline
  - Annual Agency-wide discipline meeting
  - Tagups between discipline leads at each Center
  - Agency-wide discussions of software use, testing, etc
  - Start centrally-edited best practices document
  - Shared OneNote for tips and tricks
  - Start shared document of info for new hires

- Form an inter-Center task group to discuss which sharing methods would be beneficial
- Build on NESC technical team for your discipline
- Start with small changes and grow

Conclusion

- Thermal discipline has developed many methods for knowledge sharing over the last two decades
- Those methods have had many benefits for engineers working in thermal, increasing effectiveness and lowering frustration
- Other disciplines could benefit by adopting some of these sharing methods
- When you learn a lesson or new technique, consider the best way to share that knowledge
- Include in training for new employees

Links to Knowledge Sharing Methods

- NASA thermal share drive \\reprisal\thermal
- NASA thermal OneNote
- NASA Passive Thermal Engineering Guidebook (public)
- NESC TDT website https://nen.nasa.gov/web/pt
- NESC TDT webinars https://nen.nasa.gov/web/pt/webinar
- NESC Academy classes
- TFAWS https://tfaws.nasa.gov/