Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

Investigation of Remote Work for Aerospace Systems Engineers

ERIC VAN VELZEN

SUPERVISOR: DR. ALISON OLECHOWSKI

UNIVERSITY OF TORONTO ENGINEERING - READY LAB

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Some introductions

Eric van Velzen

- Completed Bachelor's at U of T, Engineering Science Aerospace
- Incoming Master's at U of T Institute for Aerospace Studies (UTIAS) in Space Flight Laboratory

Dr. Alison Olechowski

- Assistant Professor, department of Mechanical and Industrial Engineering
- Principal Investigator in Ready Lab *readylab.mie.utoronto.ca*

Investigation of Remote Work for Aerospace Systems Engineers

What is Remote Work?

- Our current or recent reality
- What you are doing right now: watching presentations on a video call
- Scenario in which individuals in a team or organization conduct work away from their workplace and coworkers.
- Also known as:
  - Virtual work
  - Working from home
  - Geographically dispersed work
  - Telework

Investigation of Remote Work for Aerospace Systems Engineers

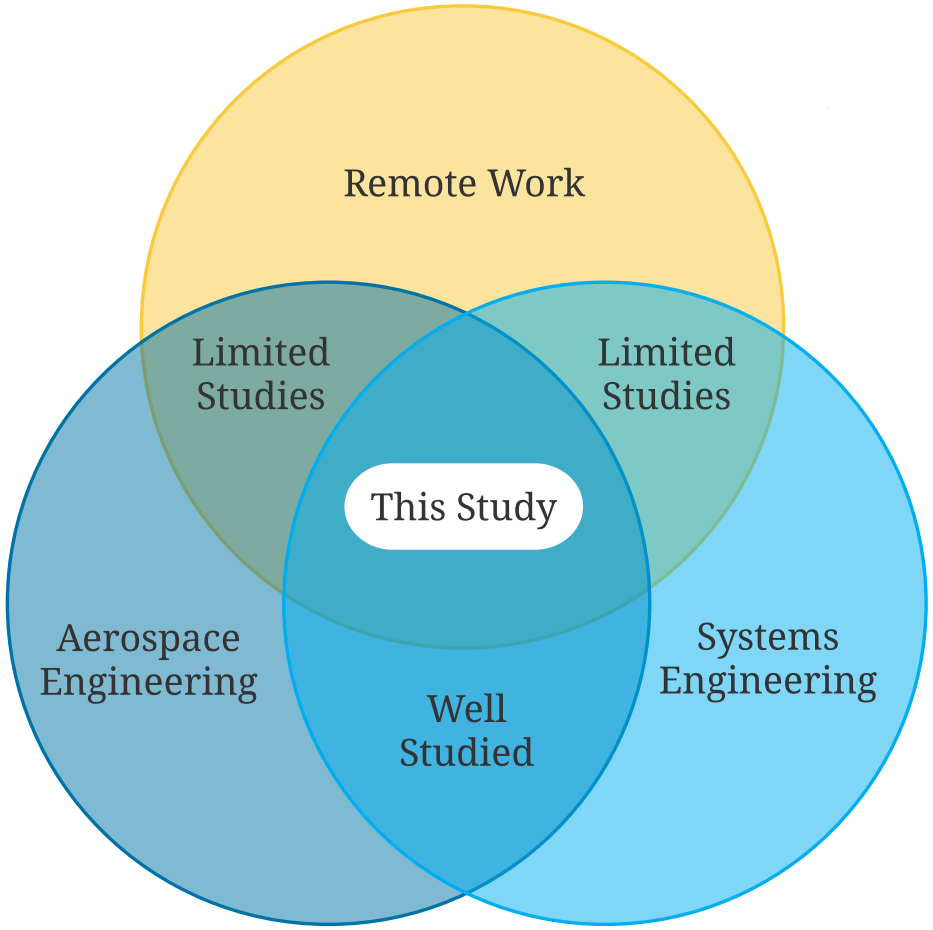
Who are Aerospace Systems Engineers (ASEs)?

- Engineering is technically challenging and complex
- Projects take many years to complete
- Collaborative and coordinated between teams, organizations, and nations
- Well established development process

Investigation of Remote Work for Aerospace Systems Engineers

The clear research gap

- This study combines instances of:
  - Aerospace Engineering
  - Systems Engineering
  - Remote work
- All individually well studied, distinct gap when combined
- ASE work requires collaboration, coordination, and documentation



The clear research gap

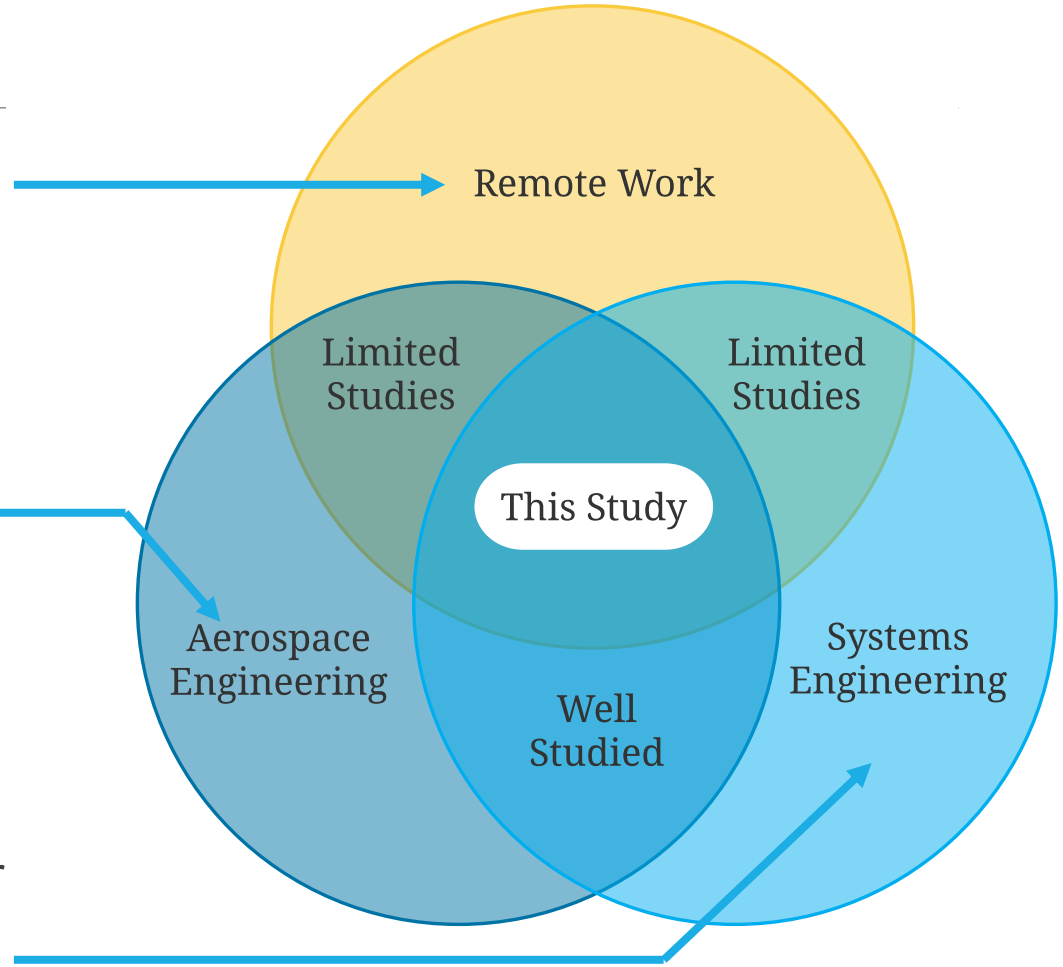
Many sources. Major literature review from 2020:

- Morrison-Smith, S & Ruiz, J 2020, *Challenges and Barriers in Virtual Teams: A Literature Review*

An entire engineering discipline and industry

Well established engineering discipline. Example:

- *INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities*



The clear research gap

Some studies, remote engineering in general:

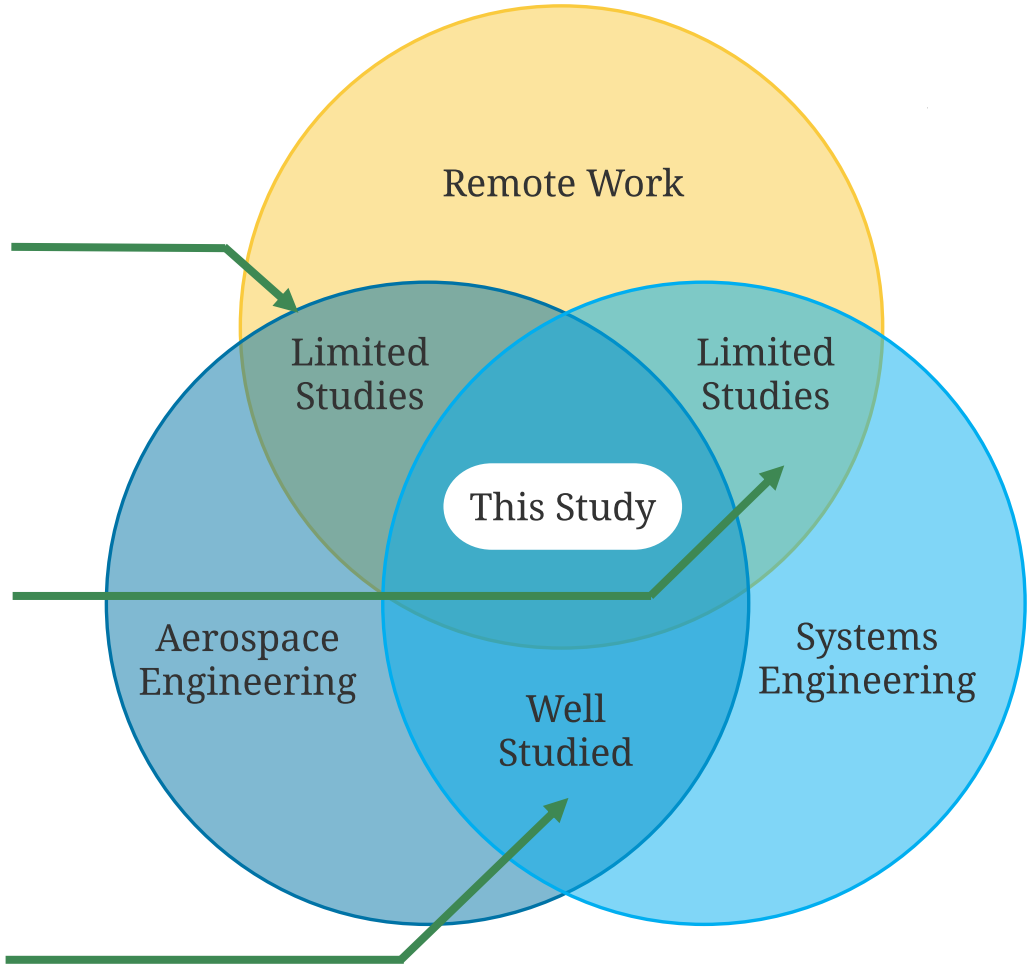
- Lumseyfai, et al. 2019, *Best Practices Framework for Enabling High-Performing Virtual Engineering Teams*

One paper mentions subject, with limited relevance and 20 years old

- D. Harris, 2001 *Supporting Human Communication in Network-Based Systems Engineering*

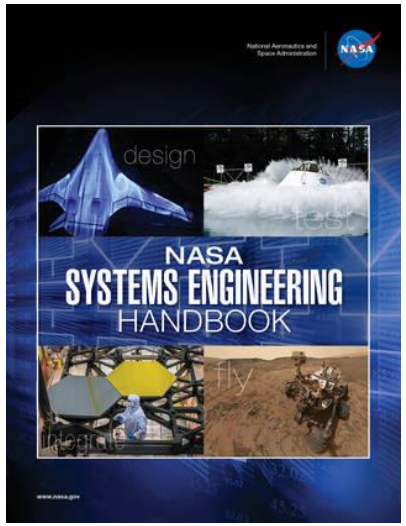
Well established engineering discipline. Example:

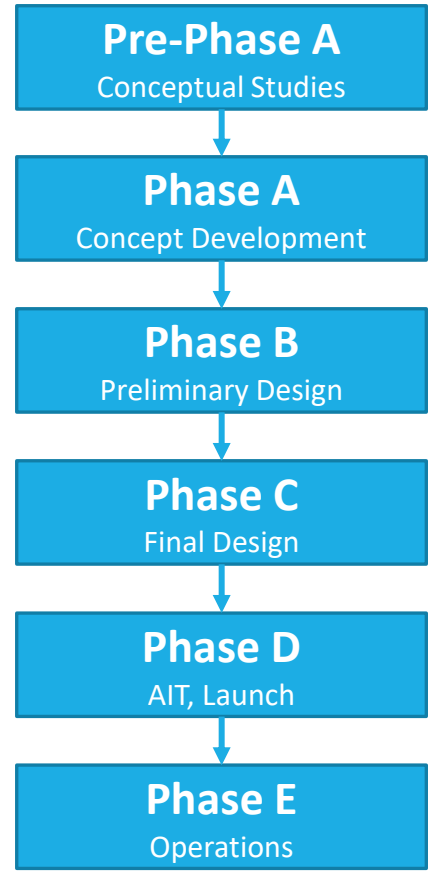
- NASA System Engineering Handbook
- Fortescue et al. 2011, *Spacecraft Systems Engineering*



Hypothesis 1: Design reviews will experience challenges due to remote work

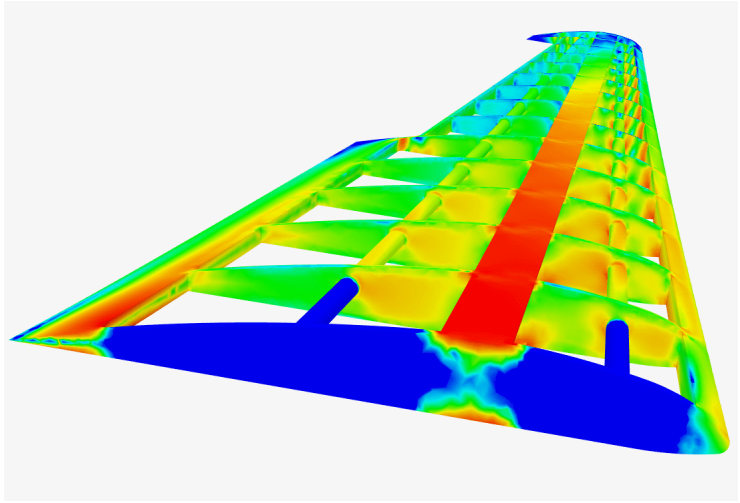
- ASE development process broken into phases
- Type of work varies by phase – conceptual in A, manufacturing in D, operations and monitoring in E
- Design reviews are important checkpoints in project between each phase
- Interactive presentation between contractor and customer to ensure customer is satisfied
- DRs depend on communication and are traditionally co-located → *Hypothesis 1*

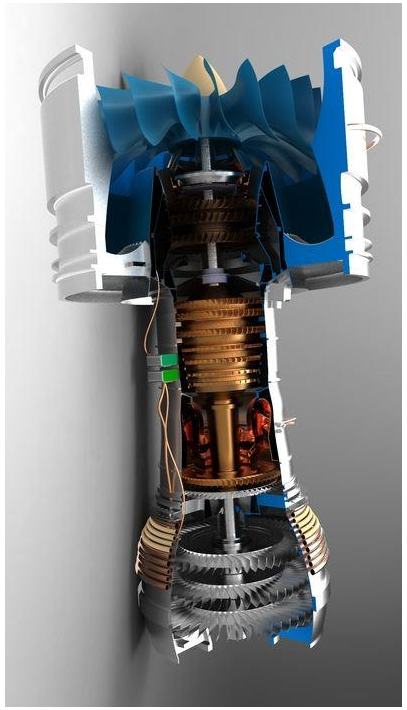




Hypothesis 2: The creation and use of artifacts will have changed due to remote work

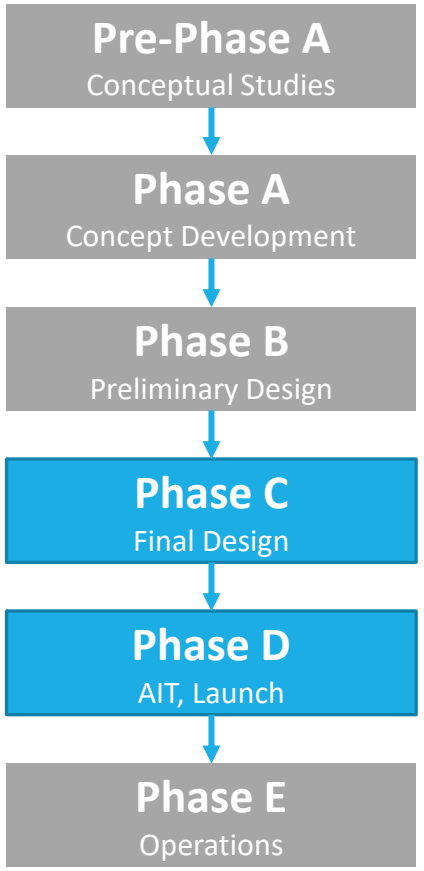
- **Artifact:** A representation of work done, used or produced during the systems engineering process, generated internally or externally, and created as a deliverable or to support other work
- Artifacts vary widely in form and function
- A change to remote work may change the process for creating artifacts, for example, from synchronous to asynchronous collaboration
- New artifacts may be created to support remote work

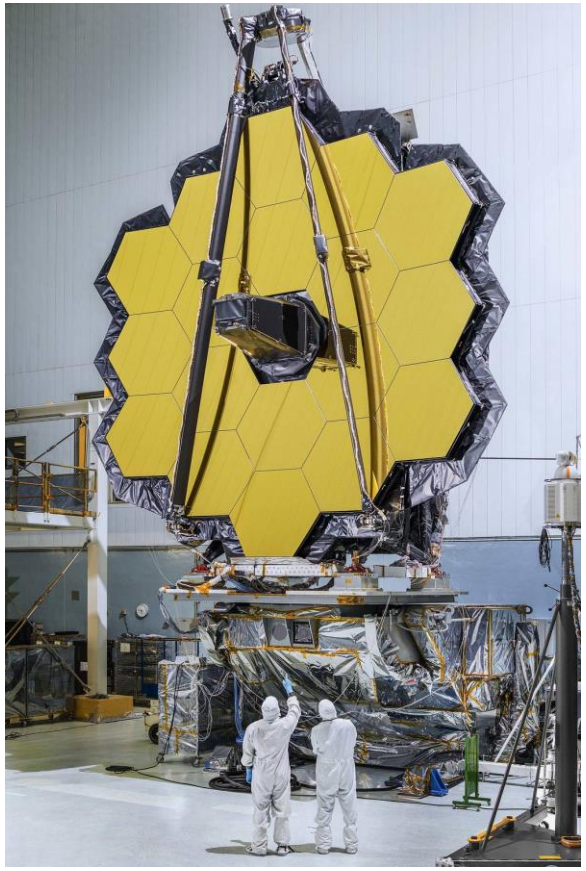




Hypothesis 3: AIT activities will experience challenges due to remote work

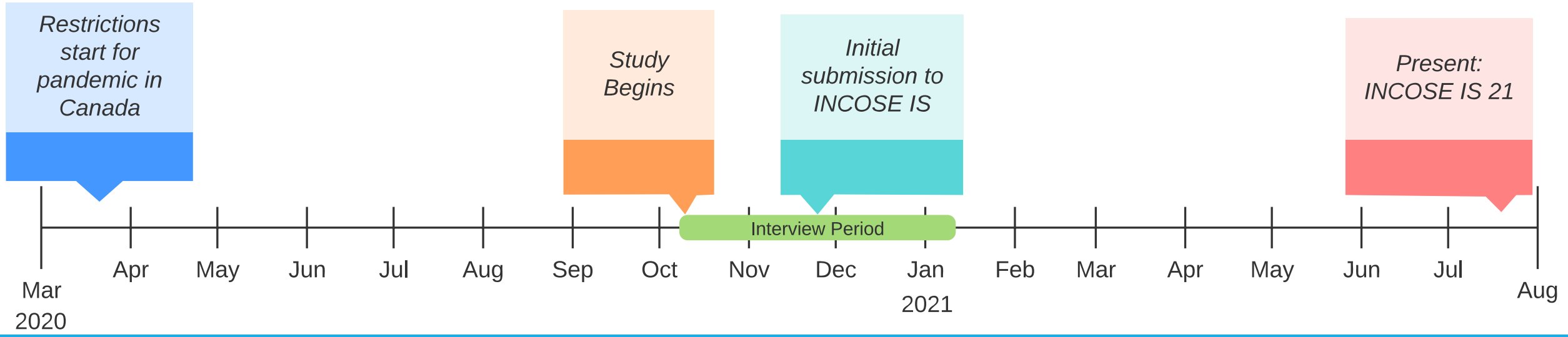
- **AIT** – Assembly Integration and Testing
- Tasks that take place in Phases C and D, and final work before a project commences operations
- Each of Assembly integration and testing activities place requirements to interact with hardware
- Complex systems require extensive testing in specialized facilities
- All aspects of AIT require in person use of facilities and equipment → *Hypothesis 3*

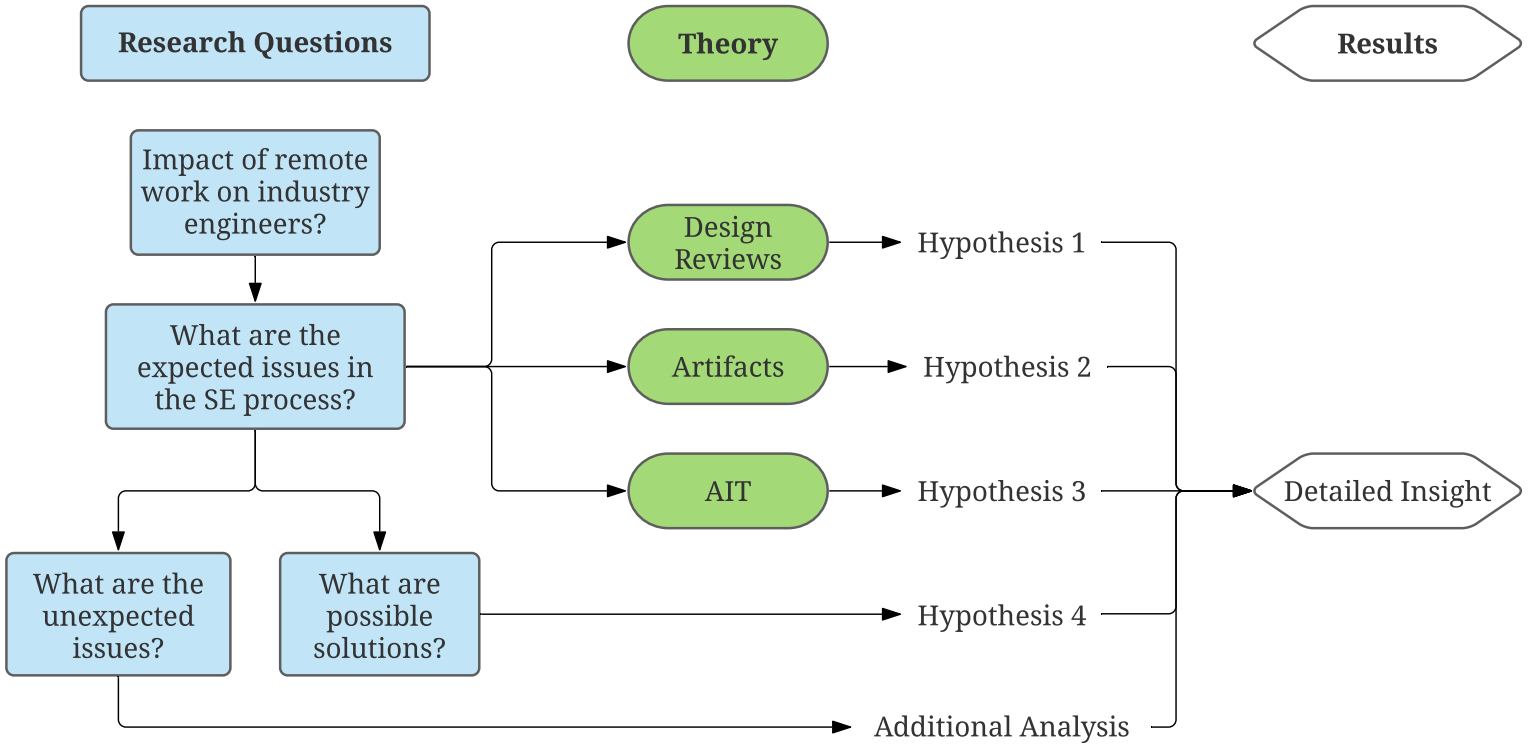




Hypothesis 4: Solutions created or implemented by ASEs exist

- **Goal of study:** understand the adaptions to remote work thus far, 'solutions.'
- When this study began, the region in Canada being studied had restrictions requiring remote work for seven months prior
- This is a long enough period to expect the industry to have made many adaptions or still may be moving towards implementation





Summary of Hypotheses

Methods

Qualitative methods are well suited to this study

- These methods perform well when studying new poorly understood phenomena
- Example: Cannot deliver a survey without sufficient prior knowledge of what questions to ask

QUALITATIVE IS

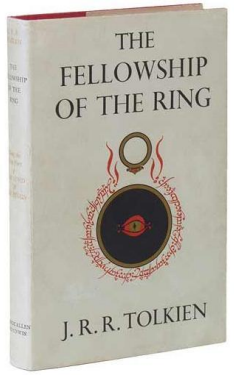
- ✓Text-based
- ✓Able to explore beyond original hypotheses
- ✓Focused on individual lived experiences
- ✓Depth-first: uncover the “why”
- ✓Small sample size

QUALITATIVE IS NOT

- ○Numerical or Statistical
- ○Suited for claims about large populations
- ○Randomized sampling

Interviews → Transcription → Coding → Analysis → Results

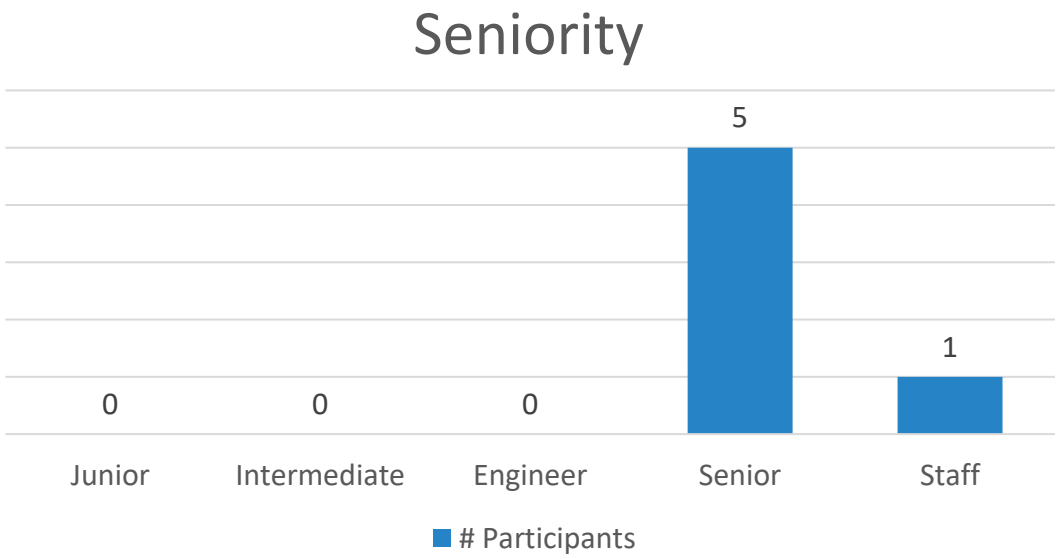
- Six participants actively employed at a single aerospace company
- Semi-structured interviews conducted one-on-one using a video calling software
- Analysis is done on interview transcripts – how much data is this?
  - Mean transcript length: ~10 000 words, totalling 60 000 words
  - Eric read this about three times, or 180 000 words
  - *The Fellowship of the Ring* by J.R.R Tolkien: 188 000 words
- *Coding* of transcripts conducted in NVivo software, categorizing statements into *nodes* based on relation to a hypothesis
- Analysis and results: understand nodes, iterate, scope and write



Participant Demographics

MEN: 5

WOMEN: 1



Discipline	# Participants
Systems	3
Mechanical	1
Software	1
Computer	1

78 years

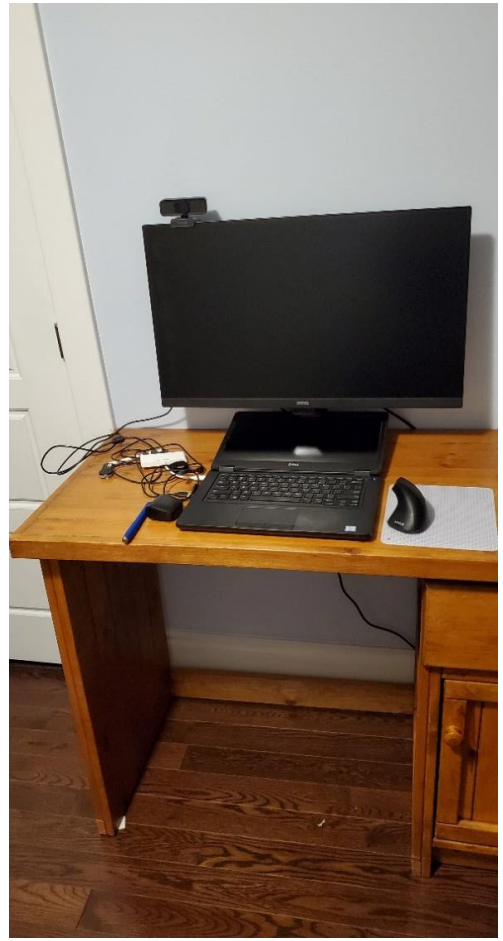
cumulative experience

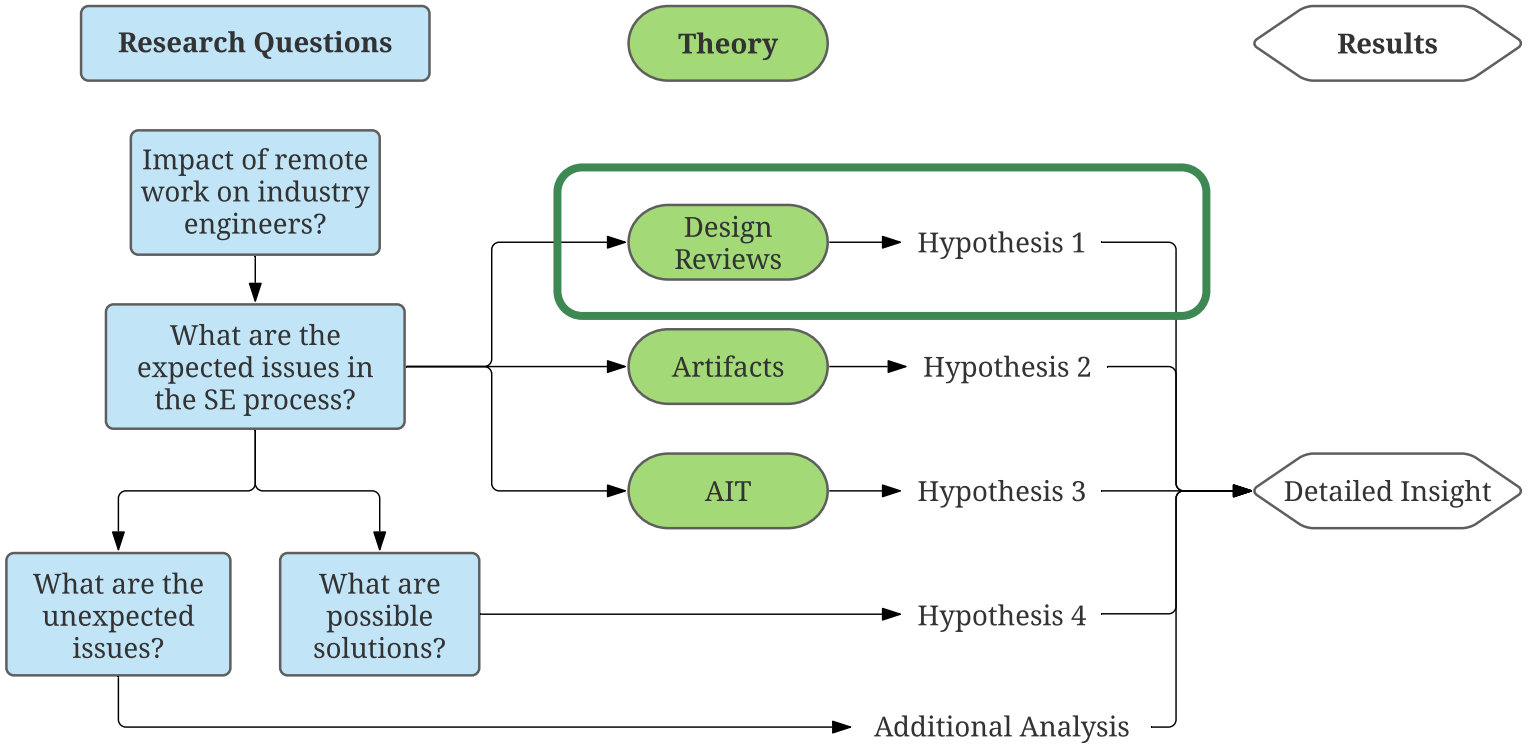
“How we do what we do is as relevant from a process perspective as the work itself, and often something that is given less attention than is warranted.”

Results

Context of remote work for results

- Remote work is new to the company as of 2020
- 80-95% of workforce remote, fluctuating
- Working from home is not a uniform experience. Home setups vary.





Design Reviews

There are both benefits and challenges with conducting DRs remotely

- Five participants were part of DRs and all feel they were successful
- A system was implemented for two DRs to be conducted remotely:
  - Small core group of facilitators co-located in an office space
  - Video conference over a Zoom session
  - A Slack text channel internal to the company was also used

"No major downsides."

Slack channel was used to *"keep people inspired and interested"*

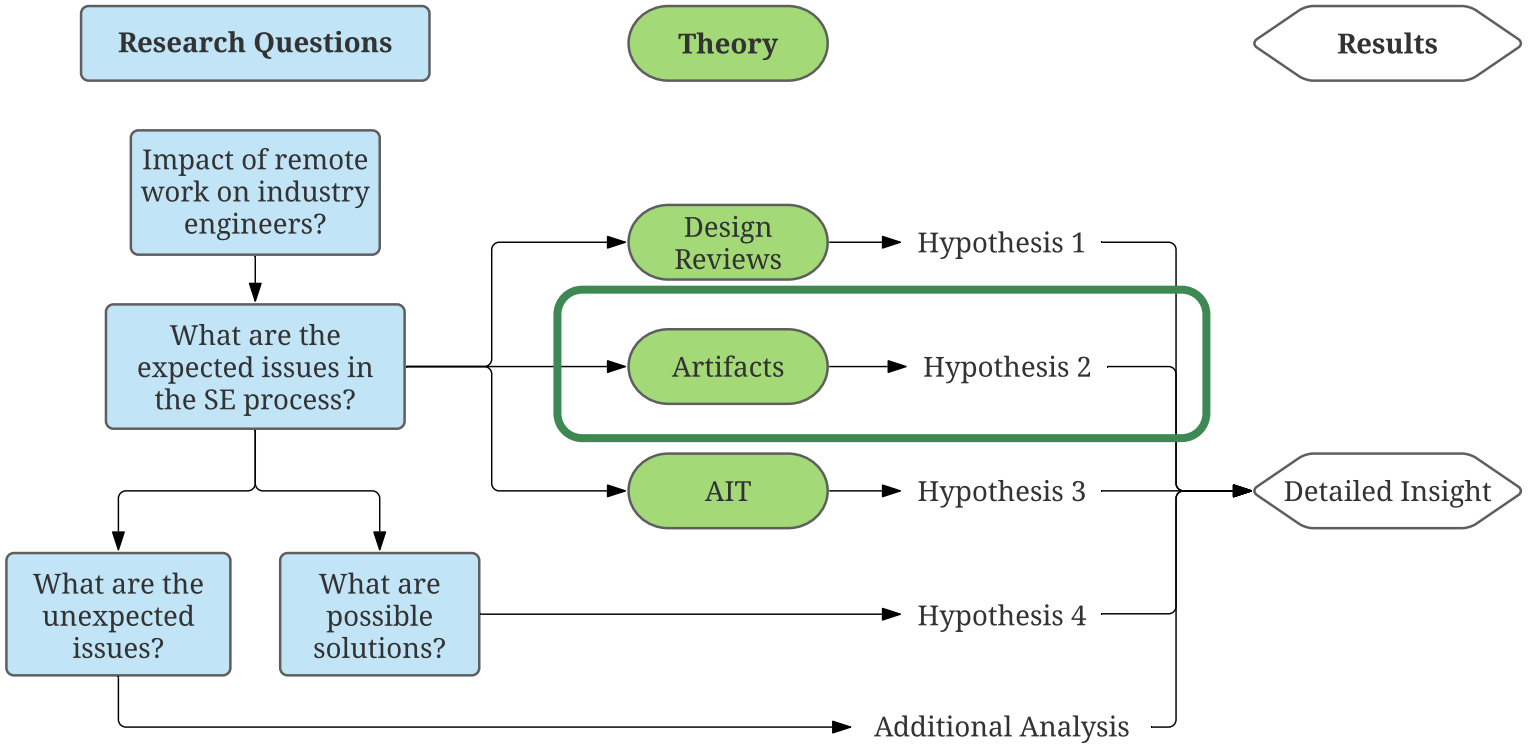
Three benefits:

1. No need to travel to customer site – eliminates travel time and cost, more individuals from the company can attend
2. Those just observing DR can work on other tasks – not everyone participates to the same extent
3. DR can easily be recorded to improve record keeping

There are both benefits and challenges with conducting DRs remotely

- Challenges are the elements missing compared to in-person DR
- Video for most individuals is off: lack of facial expression, visual cues, and opportunity to meet face-to-face with customer
- Pre-established relationships and rapport is important:
  - Participants and reviews had worked together before in previous phases including co-located interactions
  - Emphasized as a helpful condition to remote collaboration
- Future DRs: Remote or co-located?
  - **We suggest**: DRs in early phases be co-located or hybrid to promote establishing relationships

"The engineering can be good, but if you can't explain how you got to that point, then it will be to your detriment. And at these reviews, they will basically eviscerate you in front of everybody"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Theory
Results
Impact of remote work on industry engineers?
What are the expected issues in the SE process?
What are the unexpected issues?
What are possible solutions?
Design Reviews
Artifacts
AIT
Hypothesis 1
Hypothesis 2
Hypothesis 3
Hypothesis 4
Detailed Insight
Additional Analysis

Artifacts

Changes vary by artifact, its use or creation, and the individual

- What has *not* changed: what artifacts are created and how they are created
- Most artifacts are computer-based so can be worked on remotely without issue
- No new artifacts for remote work → existing artifacts sufficient
- Challenges with existing artifacts
  - Printing large sized mechanical drawings for review
  - Remote connection to CAD software running in office is slow

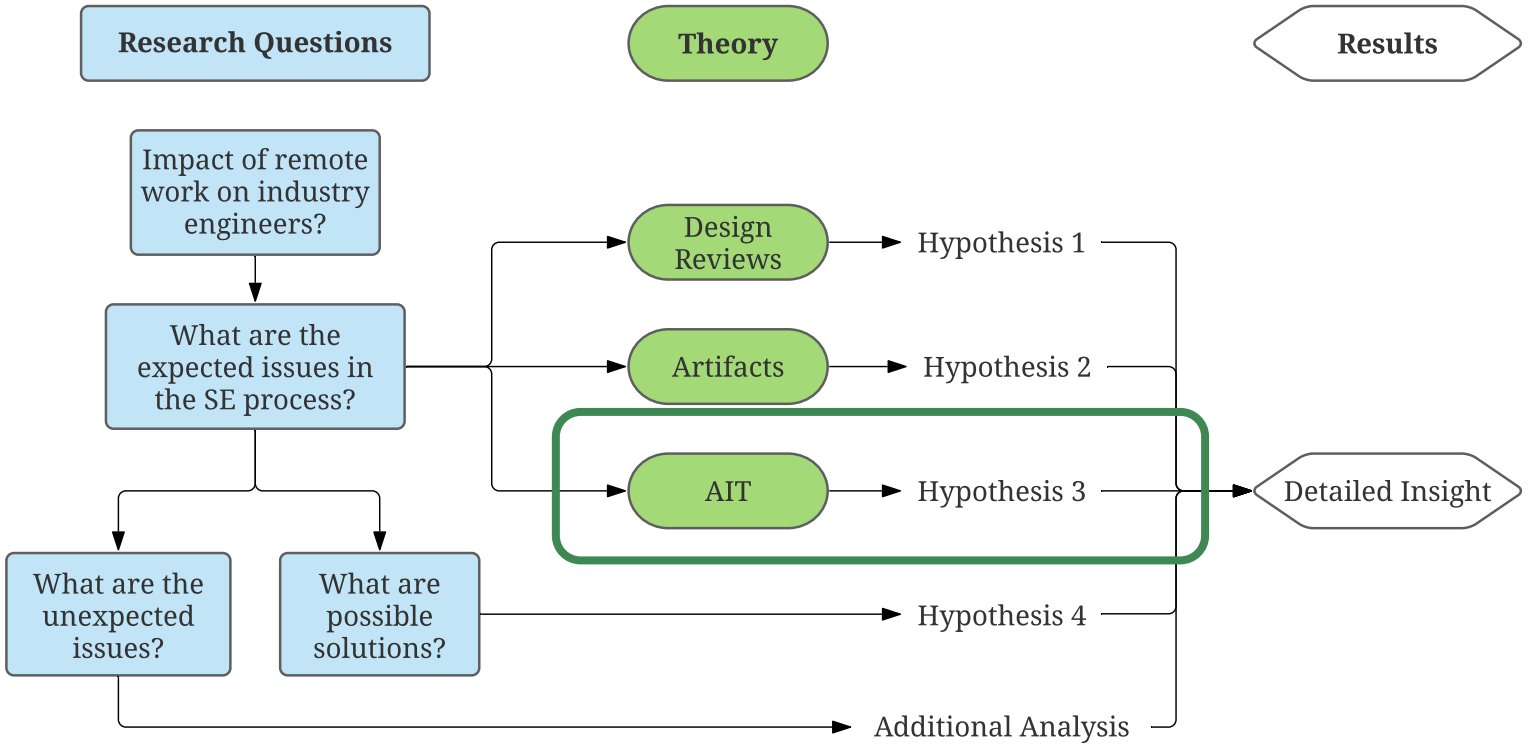
"One of the things that we do very well here is generate paper and I don't think COVID has severely impacted our production of paper."

Remote work has changed generating and reviewing artifacts collaboratively

- Collaborative work on artifacts driven by need or efficiency
- The time to get input from others or to reach out is slower when working remotely
  - Wait for a reply or schedule a meeting
- Source of slowed communication: individuals cannot go, visit and speak with others in a co-located space
- Limitations of tools: some common tools do not provide easy markup, commenting and shared editing features
- Key limitation: platforms restricted by the secure aerospace data involved

"Going through [artifact creation] collaboratively with all the different experts you need in one room is a lot easier than trying to do that, either on a Zoom call or just sending like marked-up documents out."

"I really wish you could track changes in a spreadsheet like you can in a word document."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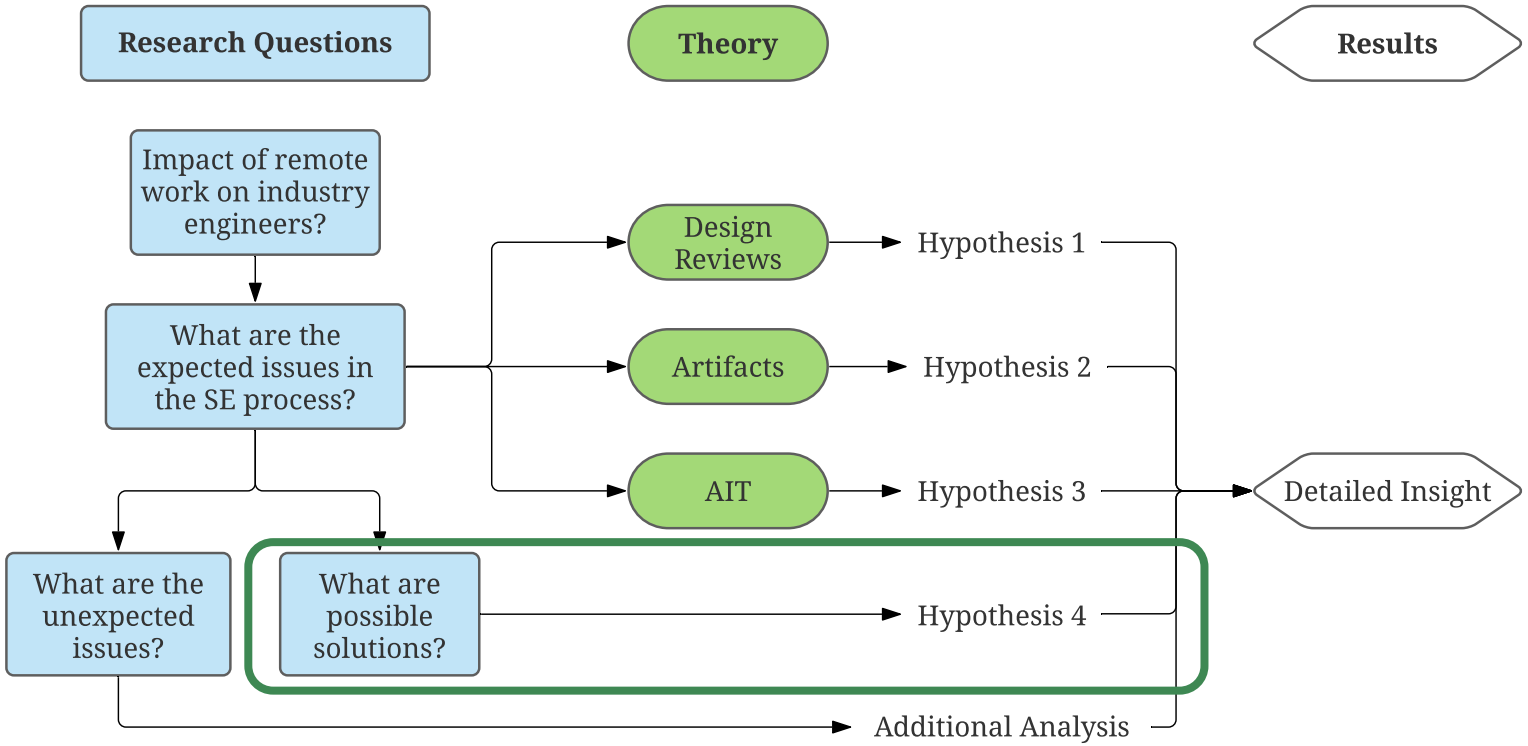
AIT

AIT has experienced significant challenges during remote work

- Note: AIT still occurred in-person in the building, but on-site activity was limited
  - A small number of technicians were regularly on-site
  - Engineers (the participants) were primarily remote
- Many challenges center around how it is difficult to communicate features of physical hardware remotely
- External supplier hardware production is impacted:
  - Cannot visit suppliers in-person before production
  - Cannot inspect hardware before final shipment
  - Different interpretations of CAD and drawings has lead to errors

"You're like sitting at a problem, looking at hardware, looking at a reference hardware, looking at the drawings and looking at a CAD model and to share that via Zoom, it's just impossible. There's no way"

"[There have been] big glaring errors that would not have made it through the chain if we were allowed to be onsite and inspect properly."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Solutions

Solution: the Slack communication platform

Slack: platform for organized instant messaging in groups

- Well suited to systems engineering work
  - Quick and informal conversation
  - Regarded as an efficient means of communication
- Does not provide records in the same way as email
- Drawback: Slack cannot send documents and data due to aerospace industry data restrictions
- At the company studied, there is disparity in the adoption of Slack
  - Some teams use it heavily while others stay with email

"A lot of the support groups don't use [Slack], which is a little frustrating."

Solution: managers limit meeting frequency

- We found helpful suggestions that managers can use to help manage their team's time
- First suggestion: managers limit meeting frequency to the same as before the remote work period.
  - Participants observed they are scheduled to attend more meetings (calls) during remote work.
  - Meetings are the core way individuals synchronously communicate when at-desk chats have been removed.
- **Why?** The increased number of meetings has a detrimental effect on the ability for individuals to focus and get work done

"The number of meetings have increased over time. Because everybody wants to talk on zoom."

"Most people on my team […] they do well working on their own. It wouldn't add to, to the team if we had more meetings."

Solution: managers host office hours

- Second (related) suggestion: managers host regular ‘office hours’ on a video or conference call, and team members is welcome to join at any time, but it is not mandatory
- **Why?** provides a designated time for team members to talk to the manager or have side discussions with other team members
- It emulates the informal side chats that occur in the office, again without increasing the number of meetings scheduled
- This method was successfully implemented by one of our manager participants

“Here's a place where you can kind of jump in and just talk. I'm trying to keep that sort of informal side chats in the Zoom format. […] I think it's, it's worth it to have that.”

Future Work

This study has uncovered numerous areas for future work

- Improve diversity: gender, sample size, number of companies, engineering disciplines
- Uniformly represented the project life cycle phases (Pre-Phase A through to Phase F)
- Extend to quantitative work: confirm hypotheses in a measurable way
- Study investigated near-term impacts of remote work, did not investigate long term impacts. For example, impact of extended remote work on design effectiveness?
- Alternatives to traditional whiteboards for remote engineering work

This study has uncovered numerous areas for future work

- Investigate role of established relationships formed while co-located during the transition to remote work
- Investigate effectiveness of DRs for teams with an existing relationship with the customer that was developed in-person
- Relationship building during remote work in general

"I'm a huge fan of people participation on teams and to do that, you need to build team spirit. You need to have people in the same room, eating cookies. It's very hard to do that remotely."

This study has uncovered numerous areas for future work

- Hardware work and supply chain during remote work: What are existing or novel solutions to the remote communication and inspection of hardware?
- Investigate communication platforms: What are the barriers to adoption of new communication platforms company-wide?
- Communication trends in general: Communication is in fact embedded in the results and discussion of all four hypotheses

> Researcher*: "Would you say that big picture thinking and the need for information flow between humans is characteristic of systems engineering in general?"*
>
> Participant: *"That is systems engineering."*

This study has uncovered numerous areas for future work

- Disparity in remote work sentiment: Participants often highlight both positives and negatives to the new experience of remote work
- Some participants wished to continue to work remotely while others made it clear it was not suited for them
- Future work: what factors contribute to personal sentiment?

"To answer your question on a personal level, I wasn't too happy about [the transition to remote work] and it wasn't my cup of tea."

"I'm way happier. I'm [financially] better off. I have more time for my family and myself, if we're happy and we're getting our work done, why do we need to come back to the office?"

Thank you for the support!

- Dr. Alison Olechowski
- ILead - Community of Practice
- Everyone at Ready Lab

Questions: ask away!