INL/PRO-21-65382-Revision-0

Accelerate Nuclear Research and Development by Reducing Time and Cost Spend in the Pre-conceptual Design Phase of Advanced Reactor Experiments

December 2021

Sunming Qin, Minseop Song, Piyush Sabharwall, Aaron S Epiney

Changing the World's Energy Future

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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Accelerate Nuclear Research and Development by Reducing Time and Cost Spend in the Pre-conceptual Design Phase of Advanced Reactor Experiments

FY22-Q1 LDRD seed call presentation

December 2, 2021

· Principal Investigator: Sunming Qin
· Co-Investigators: Minseop Song
Piyush Sabharwall
Aaron Epiney

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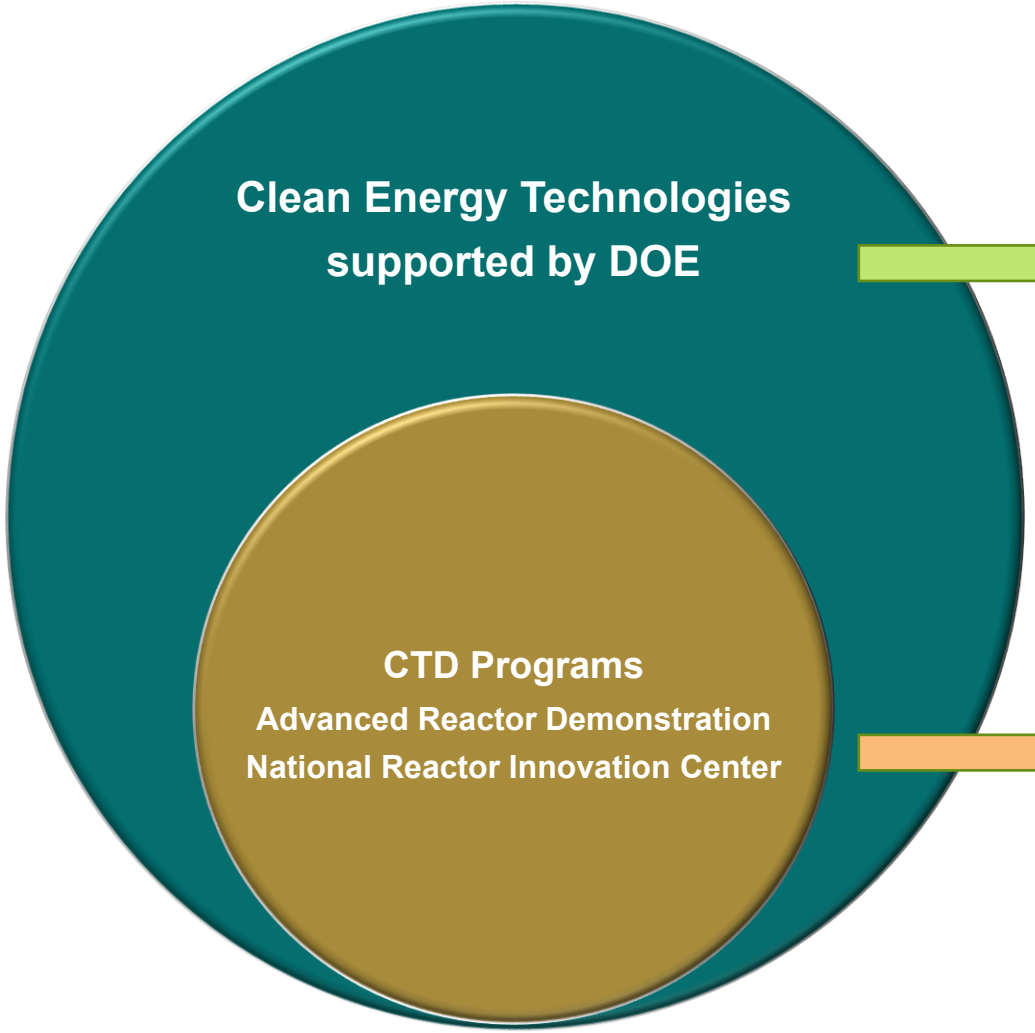
During a pre-conceptual design phase, which tool to select balancing cost and efficiency?

- The current and widely used approach for pre-conceptual design is that the design engineer sets up a set of simple equations tailored to his problem and then tries to solve and optimize them in an environment of his choice (e.g., MATLAB, Excel, Python, etc.).
- Detailed solutions such as provided by high fidelity methods like computational fluid dynamics (CFD) and even lower fidelity tools such as system or subchannel codes are usually not used *due to the long and expensive computation cost*.
- Also, it is not feasible and flexible to quickly investigate different combinations of components, individual component sizes and material properties…
- There clearly is **a lack of a flexible and user-friendly scoping tool** that can be used during the pre-conceptual design process before higher fidelity tools come into play.

Funding Opportunities for Accelerate Nuclear RD&D



DOE Budget (FY22 Request*)

- Plan to quadruple clean energy research government-wide in 4 years
- More than $8B (or 27%) over 2021 funding in clean energy technologies (including advanced nuclear technology)

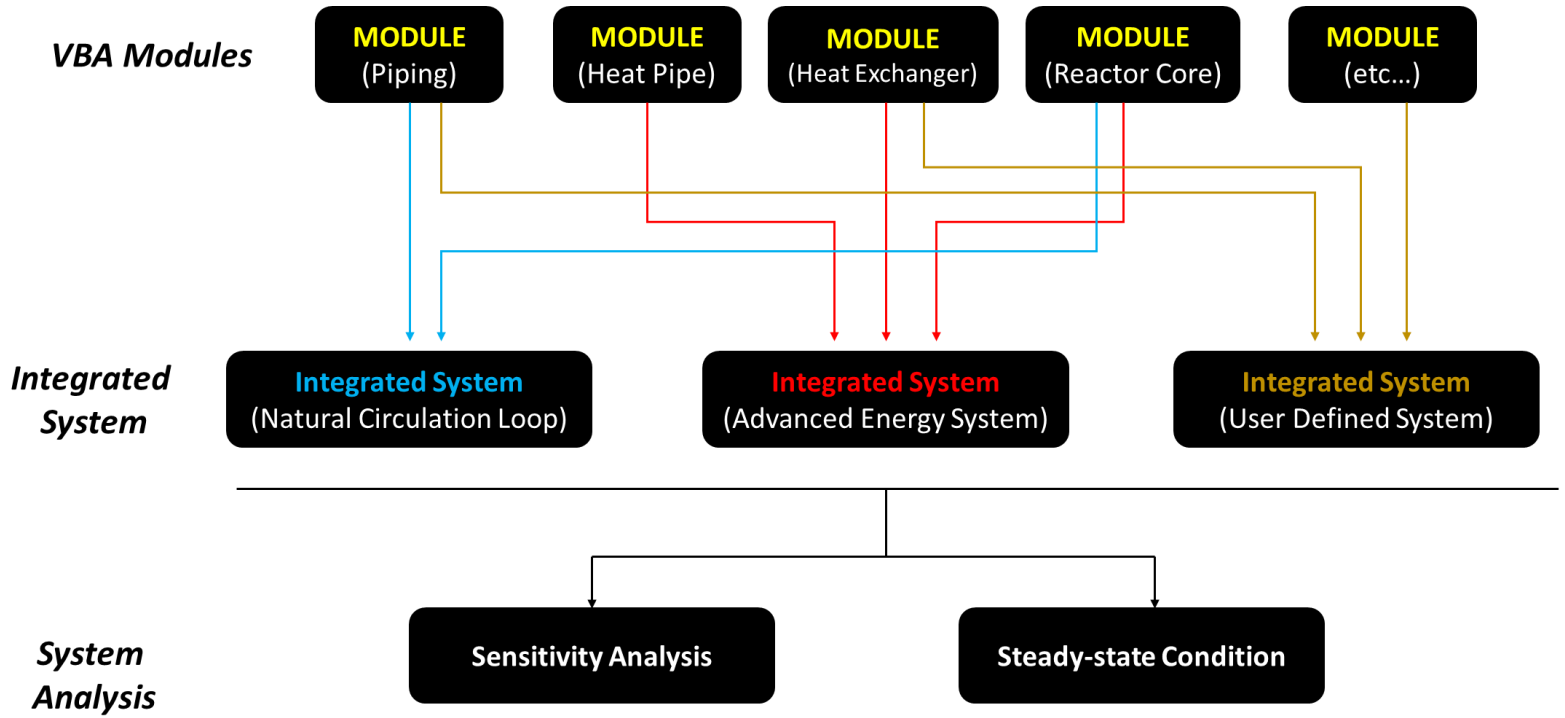
DOE Budget (FY21 Request**)

- Advanced Reactor Demonstration Program (ARDP, $20 M)
- Reactor Concepts RD&D ($111.5 M)
- Nuclear Energy Enabling Technologies ($116 M)

*Office of Management and Budget (2021), Summary of the President's Discretionary Request.
** Office of Chief Financial Officer (2020), Department of Energy FY2021 Congressional Budget Request.

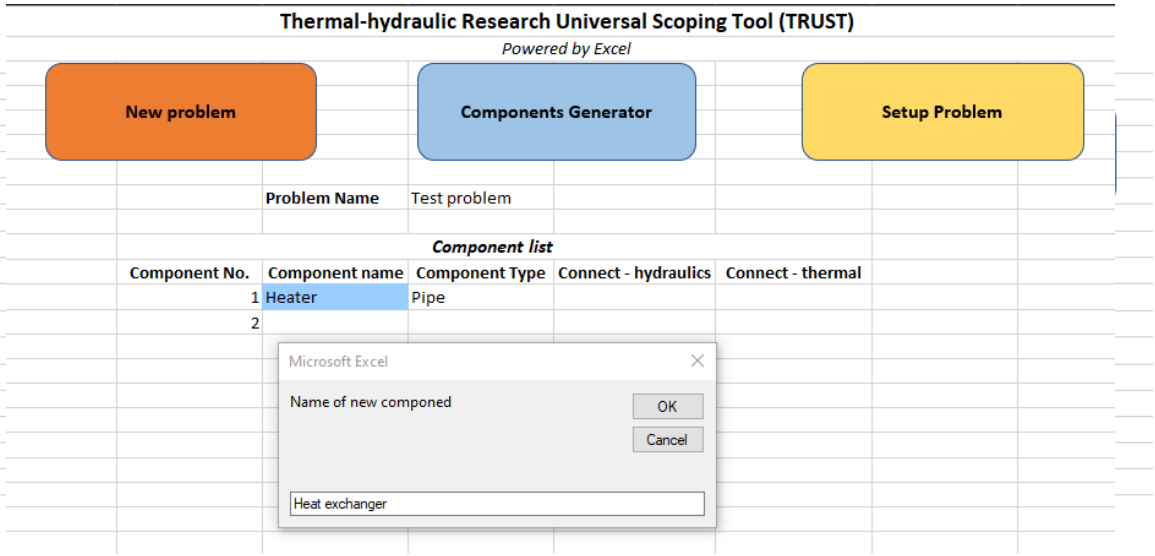
The Proposed *Solution:* Thermal-hydraulic Research Universal Scoping Tool (TRUST)

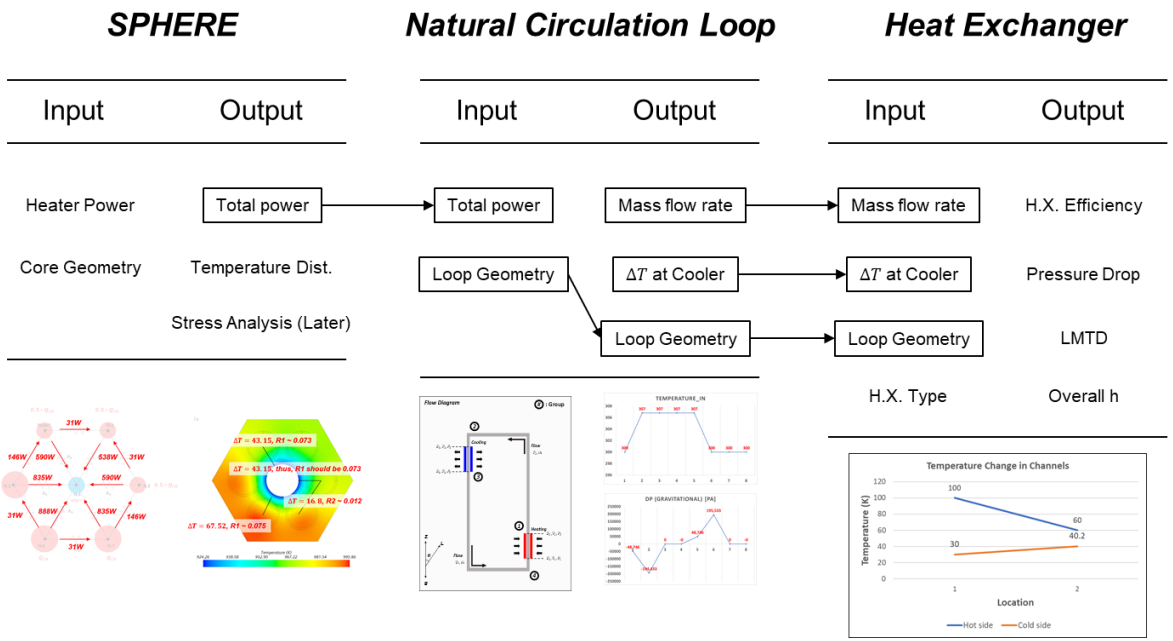
- VBA modules as building blocks including the physics and material properties.
- By connecting the modules, Integrated system can be created as needed.
- Integrated systems can be analyzed alone or inter-connected to form a more complex environment.



The Proposed *Solution*: *TRUST* *Overview and Example*

- TRUST Conceptual Overlook:
  - Easy-to-use user interface;
  - Click-button to generate components;
  - Drop-down list to assign component type;
  - Potentially, to achieve network visualization in Excel utilizing graph theory.





- Illustration: Calculation Flow for TRUST
  - With single heat pipe experiment, natural circulation loop and heat exchanger.
  - Variables passing through different components and systems.

Research Team

- Professional Team & Strong Teamwork
  - **Sunming Qin (PI)**
    - Postdoc fellow; coupled temperature-stress modeling, CFD analysis, experiment support (microreactors and advance reactor designs)
  - **Minseop Song (Co-PI)**
    - Postdoc fellow; thermal modeling/experiment, computational analysis (microreactors and advanced reactor designs)
  - **Piyush Sabharwall (Co-PI)**
    - Senior staff research scientist; advanced reactors (gas cooled, molten salt and liquid metal cooled); advanced energy systems (microreactors and VTR)
  - **Aaron Epiney (Co-PI)**
    - Senior staff research scientist; nuclear thermal-hydraulics, system design and modelling, multi-physics simulations (coupled neutronics and thermal-hydraulics)

Technical Merit

- The proposed excel-based code, ***TRUST***, is a unique scoping tool and offers a number of benefits such as:
  - ✓ User-friendly and quick learning curve;
    - Allow promptly (potentially within minutes) model setup and execution.
  - ✓ Open-source and affordable with Microsoft Excel framework;
    - Administrated by INL software license process and export control review.
  - ✓ Universal with a wide range of TH designing features.
    - Consist of a wide range of physics, special models and closure laws from which the designers can choose and tailor for their specific problem.
    - In-cooperates a thermal-hydraulic and mechanical property library for a variety of materials and coolants.

Milestone & Deliverables

Fiscal Year	FY22									FY23		
2022 Month	1	2	3	4	5	6	7	8	9	10	11	12
Module Development	■	■	■	■								
Integration				■	■	■	■					
V&V Study							■	■	■	■		
Standardization										■	■	■

- A novel Excel-based scoping tool, *TRUST*, as well as universal VBA coded modules that can be used in other excel calculations.
- V&V study with existing literature and experimental database in various forms of system.
  - Case studies: natural circulation loops, SPHERE facility, etc.
  - Uncertainty quantifications.
- User manual will be developed for code distribution and standardization stage.
- Other deliverables: milestone report, research publications...

Expected Results

- Deliver an innovative, powerful but user-friendly Excel-based code which can eminently reducing cost in the pre-conceptual TH design phase.
- Support ongoing & future development efforts for reactor TH design and analysis to accelerate nuclear RD&D process.
- Software license will be processed for intellectual properties.
- Maintain INL's leadership in the research of new advanced reactor concepts.

Follow-on Funding Opportunities?

- DOE lab calls, LDRD, NEUP, ARPA-E…
- Collaboration with industrials and institutes
- Commercialization, etc.

"Anywhere" *involving the thermal-hydraulics pre-conceptual designing phase.*

Thank You
for Your Attention!

Any Questions?

Backup Slides

Some useful words in COPERNIC (Temporary)

- Pre-conceptual design of micro-reactor
- We need a simple, versatile and practical computer tool to check the feasibility of pre-design.
- This tool can do a parametric study for
- The physics for every components closely coupled with each other, therefore it requires easy coupling of~~
- Similar case: CEA: COPERNIC/CYCLOP (for Gas-cooled reactor)
- Purpose
  - Pre-sizing of components
  - Describing the energy conversion system
  - Quickly evaluate the consequences of the modification of the operation setpoint
  - Build a database of reactors parameters which provides the data necessary
- How it works
  - Tool: Excel and VBA language
  - VBA function library is used to calculate all the necessary physical data
  - Perform parametrical exploration with tool
  - Optimization using EXCEL solver
- Copernic tool
  - Structure
    - A library of functions providing physical data for fluids and materials
    - A set of functions (correlations) relative to specific physical problems
    - A set of spreadsheets describing reactors (examples)
    - Excel Solver
  - Advantage
    - Quick calculation -> quick parametric study
- CYCLOP tool: a computer tool implementing an automatic resolution of mass and energy balances of any reactor
  - An interface tool to compose up the cycle
    - Several fluids are available including gas mixture
    - Various components are available
    - Highly flexible model
  - Input
    - Describing the configuration
    - Setting some numerical values
  - Output
    - Almost a mirror of the input part
    - Highlighting some contradictions in the calculation

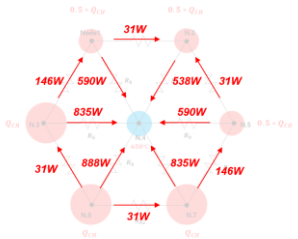
Related Research

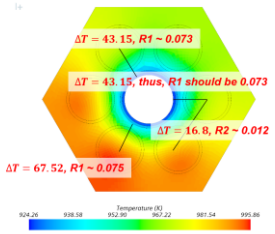
- COPERNIC / CYCPOP
- ModSim (https://ep.liu.se/ecp/096/103/ecp14096103.pdf)
  - ORNL, Dynamic System Modeling Tool (MoDSim) to facilitate research and development related primarily to instrumentation and controls studies of small modular reactors
    - Web-based interface using Xogeny's FMQ platform for model configuration
    - Local application deployment for simulation using FMI Add-in for Excel form Modelon

Example: Calculation Flow for TRUST

SPHERE

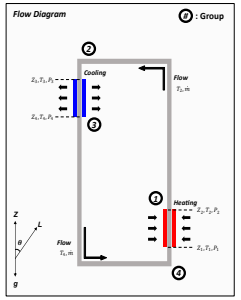
Input	Output
Heater Power	Total power
Core Geometry	Temperature Dist.
	Stress Analysis (Later)

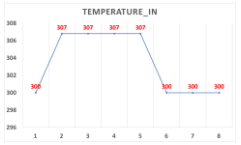


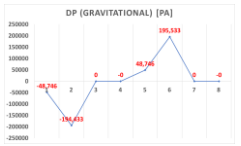


Natural Circulation Loop

Input	Output
Total power	Total power
Loop Geometry	Loop Geometry







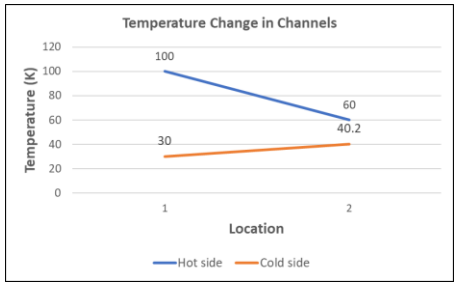
Heat Exchanger

Input	Output
Mass flow rate	Mass flow rate
ΔT at Cooler	ΔT at Cooler
Loop Geometry	Loop Geometry
H.X. Type	Overall h

H.X. Efficiency

Pressure Drop

LMTD



CO★STAR PowerPoint Template

The questions you need to answer, and a few tips to help you develop your own compelling pitch

Idaho National Laboratory

Table of Contents

Intended as a tool for use by author, may delete or keep for actual pitch as needed

This deck proposes a starting structure and the basic questions you should answer to create a compelling value proposition. You should always tailor the deck to your audience and think through what it is you want from them. Feel free to change the headings, the order, etc. to best tell your story. You will find touching on the six CO★STAR areas helps paint a complete and persuasive picture of your idea.

A few other tips:

- **Less Is More:** Limit your pitch. Keep other slides in the appendix and share them if needed
- **Visually Compelling:** Use imagery to help tell your story. A picture is worth a thousand words and can clarify complicated topics. If you have a complex image, build up to it in layers.
- **Keep it Simple:** Don't put too much text on the slides. You want the deck to to look clean, not busy. You want the slides to amplify what you are saying, not distract from it
- **Engagement Is Critical:** Encourage questions and allow time at the end for discussion. This gives you a chance to fill in gaps, correct misconceptions, and build support for your idea.

Hook (Introduction)

What is a quick way I can orient the audience to what I will be presenting?

Tip: Provide proper context for your presentation by offering a one line CO-STAR or mission statement. The audience should be clear on the topic they will be learning about.

- Every idea is different and so is every audience, but you might try this formula. “I want to tell you about how (your solution) will enable (target customer) to (get specific results) better than (the competition).”
  - For example, “I want to tell you about how our cloud computing security solution not only protects sensitive government data from malware but also detects and prevents attacks from hackers and thieves 60% better than traditional encryption methods.”

Customer

Who is the customer for your solution and what is their unmet need?

Tip 1: Clarify **who** will care about your innovative idea

- Government and/or Industry?
  - DOE, DHS, NASA, Office of Naval Research, etc.
  - PG&E, Westinghouse, Nippon, Honeywell, etc.
- Users?
  - Agency staff, warfighters, engineers, citizens, etc.
- If no one is being helped….no one will care

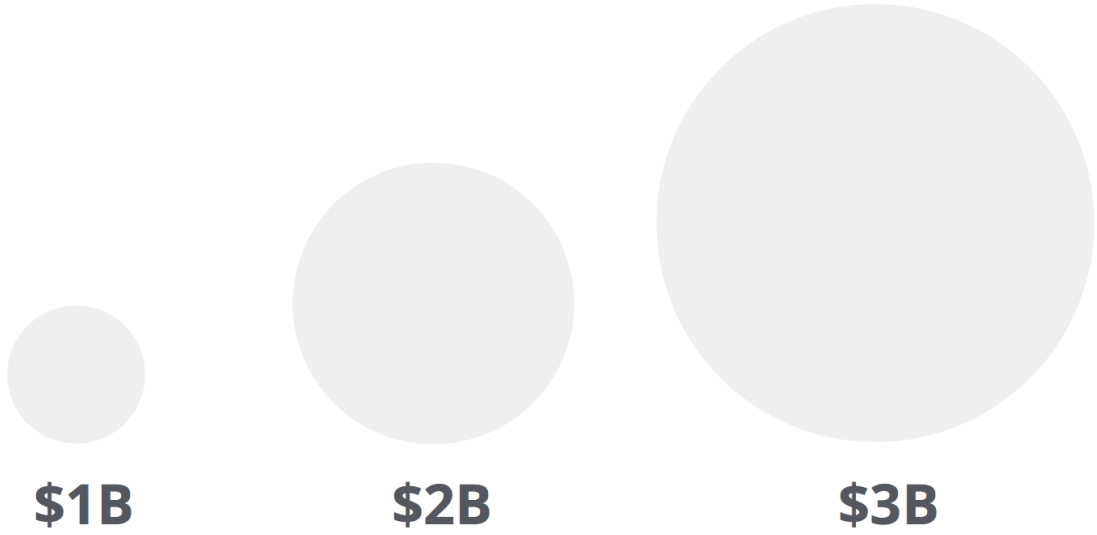
Tip 2: Describe "the problem" you are solving for group you identified in clear terms…. **without referring to your solution**.

- Clarify why is it essential.
  - Is this a minor nuisance, or a real need of the group you identified will care?

Opportunity

What is the opportunity presented by the customer problem?

- Tip: For government, it is helpful to clarify the size, relevant trends, and potential of the mission opportunity. Or industry, clarify the size, relevant trends, and growth potential of your target market.
- How many depend or stand to benefit? The world? The Nation? All military troops? 30% of the nation's energy infrastructure?



Solution

What is your solution for addressing the customer opportunity?

Tip 1: Be sure to answer the questions…

- What are the key ingredients (technologies, devices, software, facilities, methods, etc.) that make up your solution and how will it work?
- What's new in your approach and why do you think it will be successful?

Tip 2: Use images to help tell your story

Beware: Don't fall into a big S pitch

Team

Who needs to be on the team to ensure success?

Tip1: List who is already on the team and highlight their qualifications which make them uniquely qualified to ensure success

- Their name
- Their role on the team
- Their relevant expertise
- Their organization

Tip 2: Clarify who else should be on the team or who else will be joining the team – what expertise is still needed?

Advantage

What is your advantage over the existing alternatives?

- Tip1: Clarify what makes your approach novel and why is it better. Explain the differences and your solution's superiority. You may also want to compare your solution with the latest published work. Show how does it advance the field of research
- Differentiate by compare/contrast existing solutions - or lack of one.

Product Feature Comparison

	Your Company	Competitor 1	Competitor 2	Competitor 3
Feature 1	✓	✗	✗	✗
Feature 2	✓	•••	•••	✗
Feature 3	✓	✗	✗	✗
Feature 4	✓	✗	•••	•••
Feature 5	✓	✗	✗	✗
Feature 6	✓	✗	✗	•••

This slide is 100% editable. Adapt it to your needs and capture your audience's attention.

Results

What results/benefits will your solution achieve?

Tip1: Clarify the **benefits to the customer you previously identified**. How will the idea further the mission of federal agencies or the bottom line of businesses?

- What impacts (e.g., lives saved, costs reduced, cyber attacks prevented, profits generated, time to market condensed) will it deliver?

Results (Optional 2nd Results Slide)

What are the returns to INL and/or our partners?

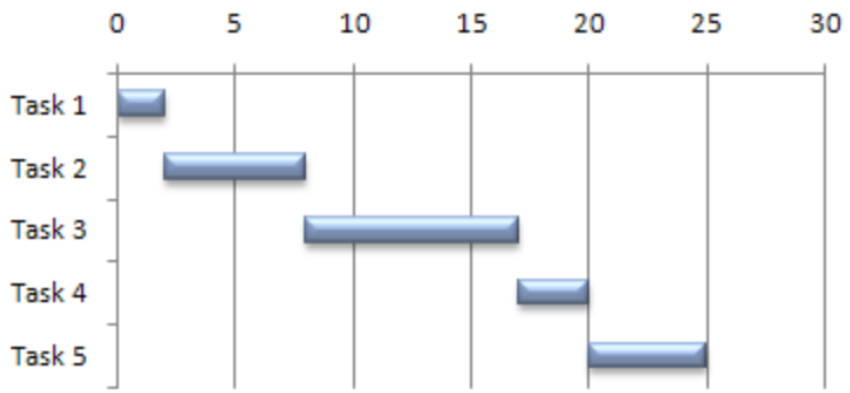
Tip 2: **For internal lab pitchers or presentations to partners, include a second Results slide**. Remember, all presentations should be tailored to your audience. Clarify…

- What is the expected follow-on funding from internal INL sources or from DOE, DHS, etc.?
- In what ways will the idea advance the field or solve a technical problem that is strategically important to INL?
- In what ways will the idea enhance INL's distinctive capabilities and/or add to its eminence (e.g., journals, conferences)?

Request/Ask

What is it you want from the audience?

- Tip: Clarify what it is you need from the audience and what you will do with their support. This may lead to a description of next steps on separate slide
- Were you just education your audience, or chatting? Do you hope to get a new Team member? A meeting, or review? Funding?

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