Systems Engineering Methodology Applied to the Sustainment of the Trans-Alaska Pipeline System

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Purpose of Study

- Examine current sustainment capability of the Pipeline.
- Address End-of-life and transition issues from a Systems Engineering perspective.

The Systems Engineering Approach

- Solve complex problems and system interactions via modeling.
- System-of-system's perspective, end-to-end, over the entire lifecycle.
- Applied early in the development to identify goals, mission objectives, and operation concepts
- Addressing goals (system validation), on-going operation and maintenance, system upgrades over time, and eventual retirement.

Systems Engineering Approach cont.

- Identifies, analyzes, and models outcomes and impacts of technical, economic, political, social, and environmental systems.
- Examines relationships and dependencies to facilitate understanding of the problems and solutions.
- Architecture that follows a structured approach to document design and development decisions.
- Provides process and structure to identify capabilities and solutions
- Systems Engineering Process provides a roadmap for improving cost and return on investment of complex systems over the entire life of the system.

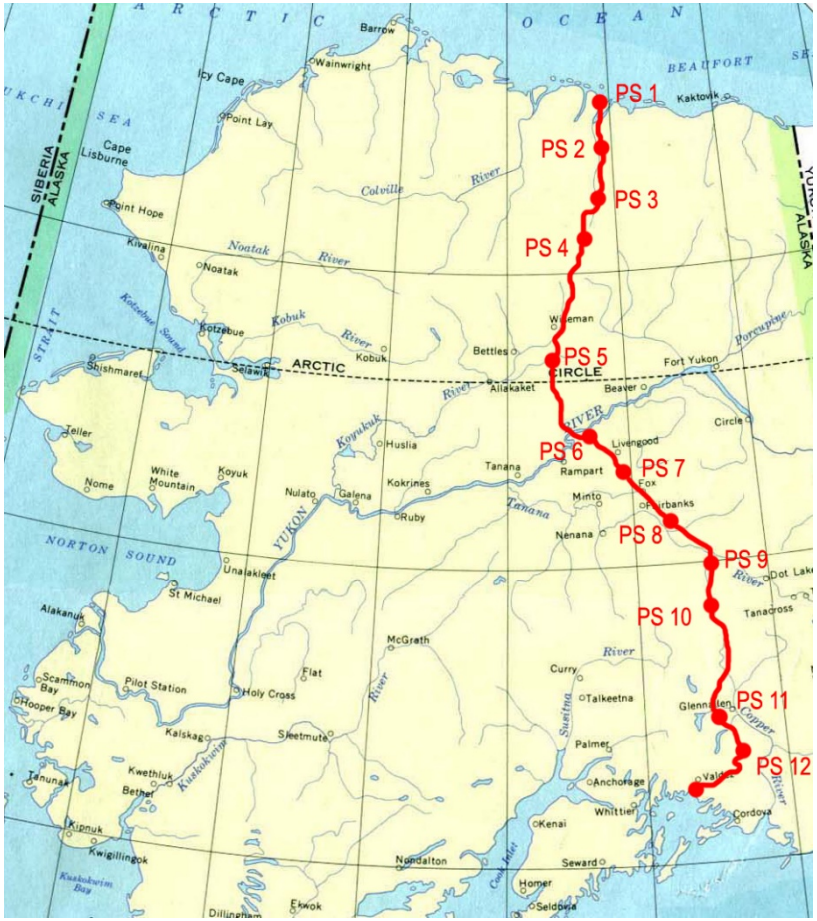
Enterprise Engineering

- Role of Systems Engineer in Enterprise Engineering
  - Captures the overall scope and elements of the problem
  - Identify the building blocks that form the EA.
  - Identifies the boundaries of the system to develop the enterprise architecture SE
  - Develops the relationships and dependencies of all elements

SE Process applied to TAPS

- **Minimizes Risks**: Improves project transparency and project control.
- **Improves Quality**: Ensures that the results to be provided are complete and have the desired quality.
- **Reduces Total Cost**: Costs of development, production, operation and maintenance of a system can be estimated and tracked by applying a standardized process model.
- **Improves of Communication between Stakeholders**: standardization of elements and terms is basis for the mutual understanding between all stakeholders.

Trans-Alaska Pipeline System (TAPS)



- One of the world's largest pipeline systems.
- Includes the trans-Alaska crude-oil pipeline, 11 pump stations, hundreds of miles of feeder pipelines, control and communications systems, and the Valdez Marine Terminal.
- Transports oil from Prudhoe Bay, to Valdez.

Photo from Wikipedia

Facts About TAPS

- Privately owned by the Alyeska Pipeline Service Company.
- Built between 1974 and 1977 after the 1973 oil crisis.
- Iñupiat people mined oil-saturated peat there for thousands of years.

Issues

- As oil production declined, so did TAPS' share of U.S. production.
  - In 2008, the pipeline transported approx. 700 thousand barrels per day less than its maximum.
  - Today, TAPS provides less than 17 percent of U.S. oil production.
  - By 2015, production could be 500,000 barrels per day unless other sources of oil are developed.
- As oil production decreases, pump stations will be closed (lower throughput requires less pumping.
- Improvements could achieve low flow-rates that would extend the life of the Pipeline.
- Low flow rates can lead to temperature drops forcing shutdowns and costly repairs.
- Some solutions have been introduced to avoid freezing, such as installing heaters at pump stations or increasing insulation.

Problem Statement

- Decline in oil production overtime will require Trans-Alaska Pipeline System to shutdown. Alaska cannot afford to shutdown the pipeline.
- Alternative uses of the pipeline need to be developed or additional sources of income/energy for Alaska must be identified and developed.
- Alaska needs access to cleaner more affordable energy to reduce the use of wood and coal that are producing air quality hazards in Fairbanks and other areas.
- The energy industry needs emergent approaches to constantly evolving opportunities, challenges and technology.

Challenges

- Stakeholders have strong interests in keeping the Pipeline operational.
- Survivability of Alaskan economy relies on tax revenue from the oil producers and shippers.
  - In 1975, Alaska's personal income tax rate was 14.5 percent—highest in the US; Alaskans earned $5 billion in personal income.
  - By 2005, Alaska had no personal income tax; Alaskans earned $25 billion in personal income derived from TAPS.
  - Approach to sustainment must be modeled within the complex environmental, economic, social and political systems.

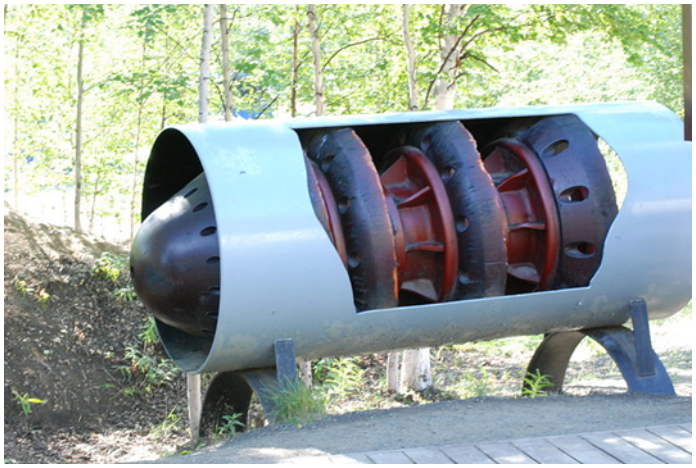
Photo from Wikipedia

Major Problems

Water/Ice - Crude oil naturally contains small amounts of water.

- As crude slows and cools, water separates out and accumulates at the bottom of the pipeline, increasing the risk of corrosion.
- The risk of ice-related problems also increases during shutdowns
- Fairbanks

Major Problems cont'd



Wax - Crude oil naturally contains up to 2 percent wax by volume.

- In pipe walls colder than 70 deg wax crystals stick to pipe wall.
- As wax precipitates out less turbulence and slower flow result in more wax sticking to pipe walls and more wax settling in the pipeline.
- Wax deposits must be removed by running cleaning pigs

Gap Analysis

- Existing Capabilities
  - Low-flow technologies or processes
- Needed Capabilities
  - Low-flow technologies or processes
  - More drilling to increase more oil and pipeline flow
  - Alternative uses of pipeline
  - Alternative sources of energy

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Existing Capabilities-Low-Flow Technologies and Processes

Adding more heat and more pigs:

- keeps crude oil warm, prevents water from freezing in the line.
- frequent pigging and redesigned pigs keep the pipe.

Heat added through recirculation at pump stations to recirculate oil.

- Infrastructure for recirculating oil at pump stations is enhanced.
- A schedule is in place for adding heat as crude cools.

Needed Capabilities: Low-Flow Technologies or Processes

Improvements to allow low flow-rates could extend pipeline lifespan as far as 2075

- "Cold dry" flow

water is removed from the crude before it enters the pipeline

eliminating the water eliminates the need for elaborate heating systems.

Once the cold dry flow system has been validated a transition phase will shift the system from heat-dependent operations to cold-dry flow.

Needed Capabilities: More Drilling to Increase Flow

"The best long-term solution is more oil" Terry Philley

Valdez Marine terminal

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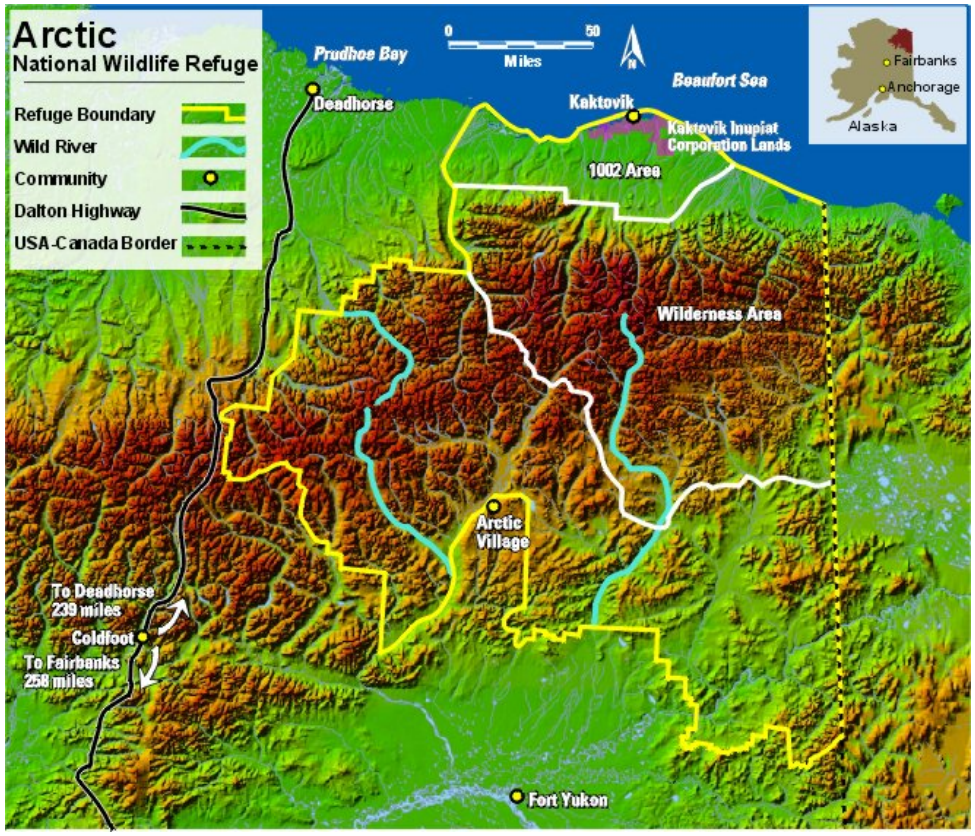
More Drilling

- Pipeline may reach minimum operating level (200,000 barrels per day) by 2020
- Trans-Alaska Pipeline System Renewal Environmental Impact Statement estimated levels above this through at least 2032 due to ongoing exploration outside ANWR coastal plain
- Drill for oil in the Arctic National Wildlife Refuge (ANWR) has been an ongoing political controversy in the United States since 1977



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Needed Capabilities: Alternative Uses of Pipeline

- Reuse of pipeline system and support infrastructure to transport other types of fuel
- Flaring natural gas wastes millions of $$
- Need to put natural gas to work

Alternative Sources of Energy

- Alaska Gas line Inducement (expected cost US$26 billion, operational by 2018).
- Opposition to the Alaska natural gas pipeline route mandate and price supports
  - Bush administration and the Canadian government.
  - The late Governor Wally Hickel

End-of Life

- Decommission and return environment to original state
- At end of life, when oil extraction is complete, Alyeska will be required to remove all traces of the pipeline.

The Reference Model-TAPS Architecture Toolkit

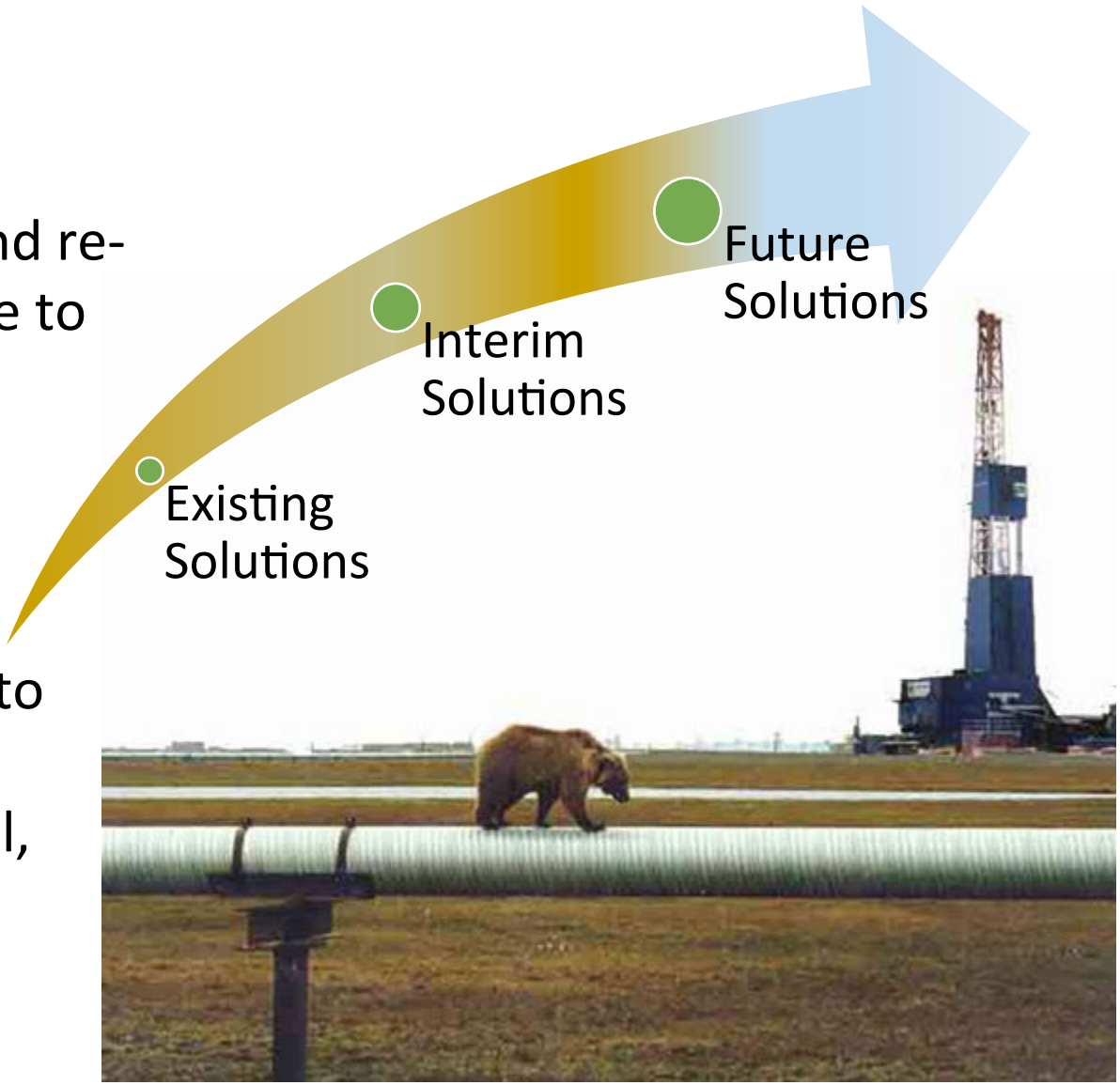
- Provides guidance for the selection of technologies to support TAPS sustainability
  - Low-flow technologies
  - More drilling to increase pipeline flow
  - Alternative uses of pipeline
  - Alternative sources of energy
- Accelerates development of cost-effective, agile, incrementally implementable, resilient solutions
- Decision Support System (DSS) facilitates assessment of technology feasibility.
- Includes modeling, simulation and reporting capabilities to accelerate the development of new technologies

TAPS Architecture Toolkit (TAPS-AT)

- Innovative: TAPS-AT provides a level of automation and risk reduction to the analysis of TAPS technologies, not currently available.
- Feasible: TAPS-AT developed from decision making tools BBII created for Northrop Grumman CANES solution, several Navy labs, for NASA, and for the State of Texas.
- Achievable: TAPS-AT is based on industry standards and builds on existing TRL-9 projects
- Complete: TAPS-AT supports full system development lifecycle.

Transitional Roadmap

Alternative uses and re-uses of the Pipeline to avoid end-of-life decommissioning



Roadmap takes into account technical, economic, political, social, and environmental impacts

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Summary

Questions