International Council on Systems Engineering
A better world through a systems approach

Why Systems Engineering Skills Are Critical for Successful Leadership of Large Complex Projects

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INCOSE International Symposium 2025 | Ottawa, Canada

Leadership of large complex projects is different than established project management practice

Research project: “the Future of Megaproject Management”

Only 8.5% of “megaprojects” complete on time & on budget.

Uncertainty kills megaprojects, can it be characterized?

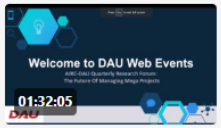
Megaproject leadership and management of uncertainty requires a unique set of skills.

A competency framework for megaproject leadership.

SYSTEMS ENGINEERING RESEARCH CENTER

AIRC ACQUISITION INNOVATION RESEARCH CENTER

DAU Quarterly Research Forums



AIRC-DAU Quarterly Research Forum - The Future Of Managing Mega Pr...

AIRC-DAU Quarterly Research Forum: The Future Of Managing Mega ProjectsThe Acquisition Innovation Research Center (AIRC) team is exploring how data visualization, Artificial Intelligence, and Machine Le...

1 Tag 1 Detail Explore

The Future of Managing Mega Projects (Benchmark Results)

The Acquisition Innovation Research Center (AIRC) team is exploring how data visualization, Artificial Intelligence, and Machine Learning can be combined with human knowledge transfer across teams to ...

1 Detail Explore

AIRC-DAU Quarterly Research Forum - Megaproject Lessons Learned 6.1...

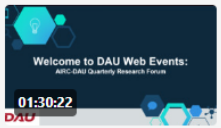
Megaproject success is strongly linked to successful management of project uncertainties. Management of project uncertainties fundamentally differs from the management of project risk. In particular, proje...

1 Tag 1 Detail Explore

AIRC-DAU Quarterly Research Forum 4a

Megaproject success is tied to the effective management of project uncertainties and the cultivation of a shared vision and action plan among team members and stakeholders. In this talk, we delve into the r...

1 Detail Explore



AIRC-DAU Quarterly Research Forum

Megaprojects are large-scale and highly complex, requiring leaders with a specific set of skills to see them successfully to completion. In this final Quarterly Research Forum by the AIRC research team, we...

1 Tag 1 Detail Explore

1. State of the practice in commercial megaprojects
2. Case Studies: benchmarking megaprojects
3. Megaprojects lessons learned and playbook
4. AI and visualization approaches to improve megaproject management
5. Skills and competencies for megaproject leaders

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What is a Megaproject?

- **large-scale, complex ventures that typically cost $1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people**."
  - *Oxford Handbook of Megaproject Management (Flyvbjerg, ed., 2017)*
- "**often produce mega-systems that operate with dimensions of behavioral complexity, pluralistic multi-actor decision-making, high criticality, and volatility of the external environment**."
  - *Engineering Mega-Systems (Stevens 2017)*
- "**often combine uncertainty with the difficulties of long time horizons and nonstandard technologies**."
  - *S. Lenfle and C. Loch, "Has Megaproject Management Lost its Way: Lessons from History." in The Oxford Handbook of Megaproject Management*

Derived Common Analytical Characteristics of Megaprojects

- Large scale, complex interfaces
- Behavioral and structural complexity, high levels of uncertainty
- Often non-standard technology & design
- Transformational outcomes
- Long planning horizons, scope changes significantly over time
- Pluralistic, multi-stakeholder influence and decision-making
- Complex external environment and over-commitment

1. **Uncertain outcomes: "Fat Tails"**
2. **Experience major lifecycle shifts**
3. **Complexity drives uncertainty and management of uncertainty**
4. **Success/failure difficult to predict, lack of causality**
5. **Specialized leadership abilities required**

The Oxford Handbook of Megaproject Management (Oxford Handbooks) (p. 8). OUP Oxford.

Uncertain outcomes: “Fat Tails”

The table shows cost overruns for twenty-five project types covering sixteen thousand–plus projects. Overrun is measured as (a) mean cost overrun, (b) percentage of projects in the upper tail (defined as ≥ 50 percent), and (c) mean overrun in the tail. Overrun is measured in real terms.

Flyvbjerg, Bent; Gardner, Dan. How Big Things Get Done (p. 191). Crown.

Many defense related projects are in areas that tend to have large mean cost overruns and a fat-tailed cost overrun distribution.

PROJECT TYPE	(A) MEAN COST OVERRUN (%)*	(B) % OF PROJECTS IN TAIL (≥ 50% OVERRUN)	(C) MEAN OVERRUN OF PROJECTS IN TAIL (%)
Nuclear storage	238	48	427
Olympic Games	157	76	200
Nuclear power	120	55	204
Hydroelectric dams	75	37	186
IT	73	18	447
Nonhydroelectric dams	71	33	202
Buildings	62	39	206
Aerospace	60	42	119
Defense	53	21	253
Bus rapid transit	40	43	69
Rail	39	28	116
Airports	39	43	88
Tunnels	37	28	
Oil and gas	34		

1. Why do we see these uncertain outcomes?

2. What data/indicators should have told us we would experience large overruns?

Most Common Causes of Fat Tail Behaviors:

1. Underestimation of or refusal to acknowledge uncertainty:
   - Assume the design and project plan can be fully defined at the beginning
2. Stakeholder neglect or mismanagement:
   - Stakeholder conflicts are a major source of project problems.
3. Inflexible contractor management:
   - Many organizations have to cooperate; transparency, honesty and incentives are needed
   - Many megaprojects fail because they are bid incorrectly or dishonestly, or just “priced to win”.

Interactions across these causes enhance project failure models

S. Lenfle and C. Loch, “Has Megaproject Management Lost its Way: Lessons from History.” in The Oxford Handbook of Megaproject Management.

Megaproject Uncertainty Framework

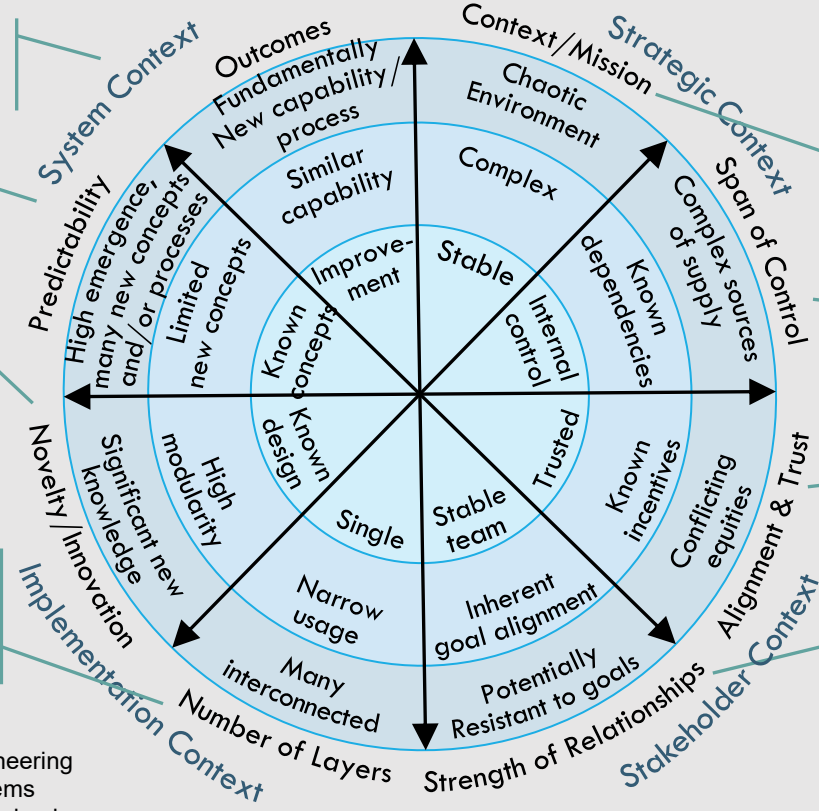
Consolidated Framework for evaluating current uncertainties in the megaproject, derived from the Mega-systems and Megaproject literature review

Transformative aspects of megaproject outcomes

Newness of megaproject technologies, processes, and uses

Megaproject state of knowledge associated with concepts & assumptions

Interdependencies across differing disciplines and domains of use



Complexity of the leader's control over and project's sources of supply

Potential for conflict between stakeholders

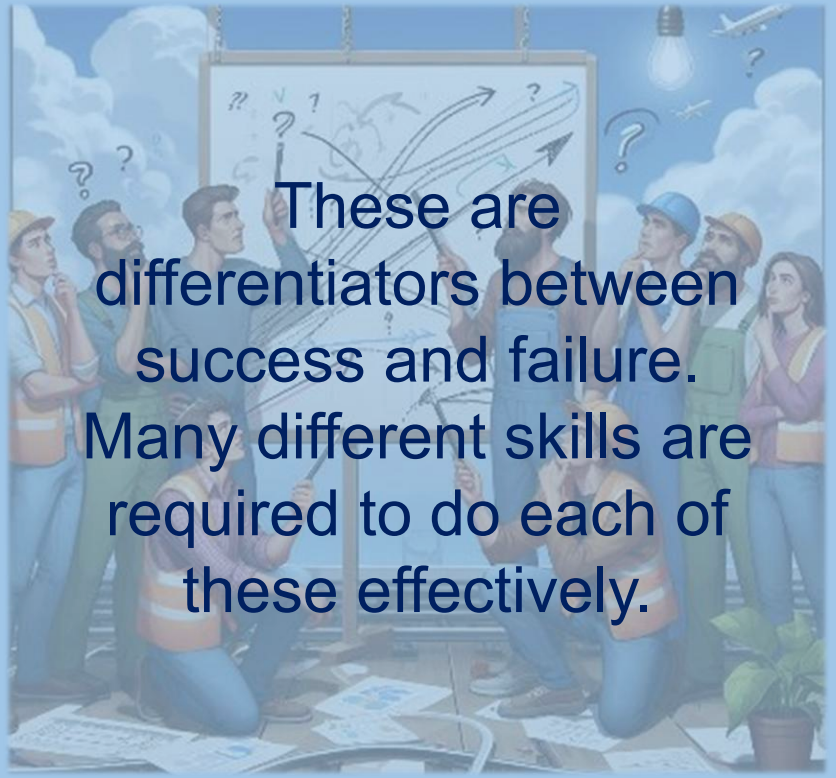
State of leader's relationship with stakeholders

State of the external socio-political environment

Adapted from Stevens, R. (2011). Engineering Mega-Systems: The Challenge of Systems Engineering in the Information Age. Auerbach Publications.

Critical Leadership Activities

- Ability to Manage Diverse Stakeholders
- Ability to Manage Complexity
- Ability to Manage Uncertainty
- Ability to Create Flexibility
- Ability to Manage Risk



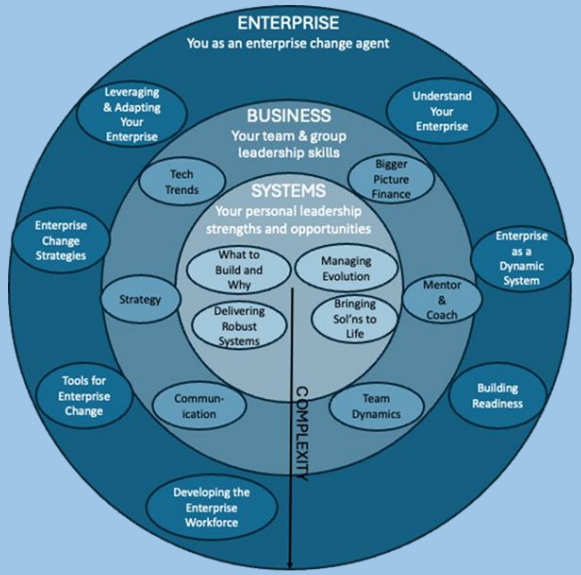
Megaproject Leadership

Traditional/Transactional leadership approaches are the *antithesis* of the approaches needed for successful megaprojects

Situational leadership – adapting your leadership style to each unique situation or task to meet the needs of the team or team members

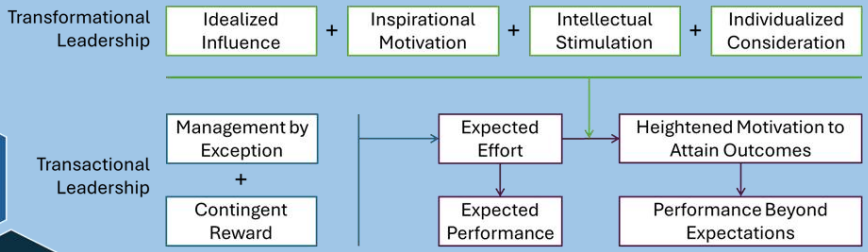
Transformational leadership – a philosophy that encourages employees to innovate and improve the company's future

Literature Review and Competency Framework

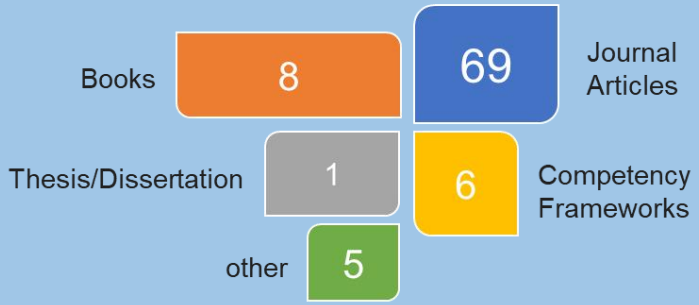


SERC/DAU Technical Leadership Framework

Helix Employability Model



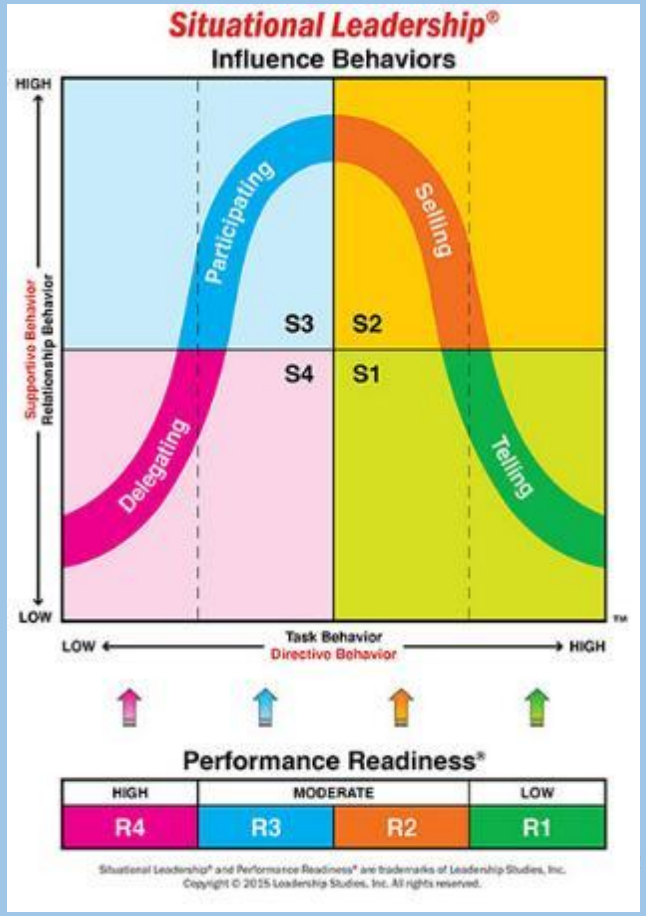
Bass Transformational Leadership Model



The International Centre for Complex Project Management (ICCPM)

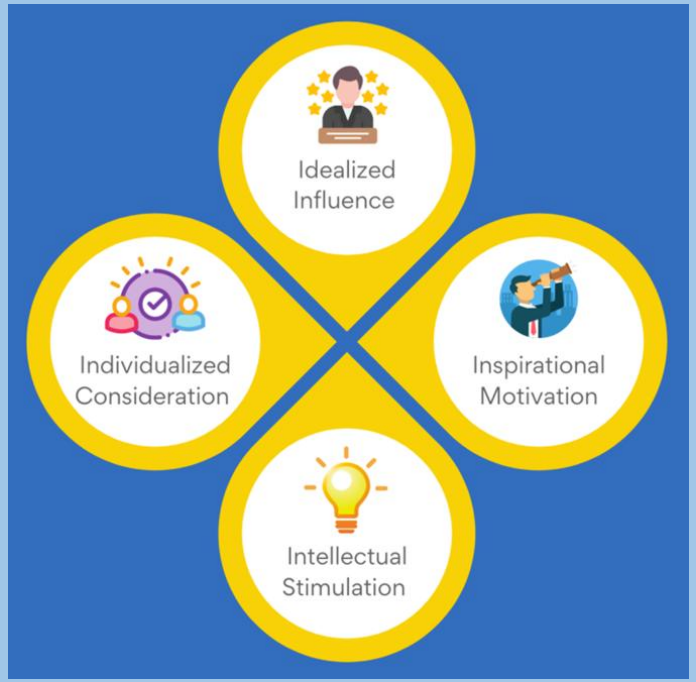
Situational Leadership

A flexible leadership style that adjusts to the needs of a team or individual. It involves matching leadership behaviors to the performance needs of the people being led.



Transformational Leadership

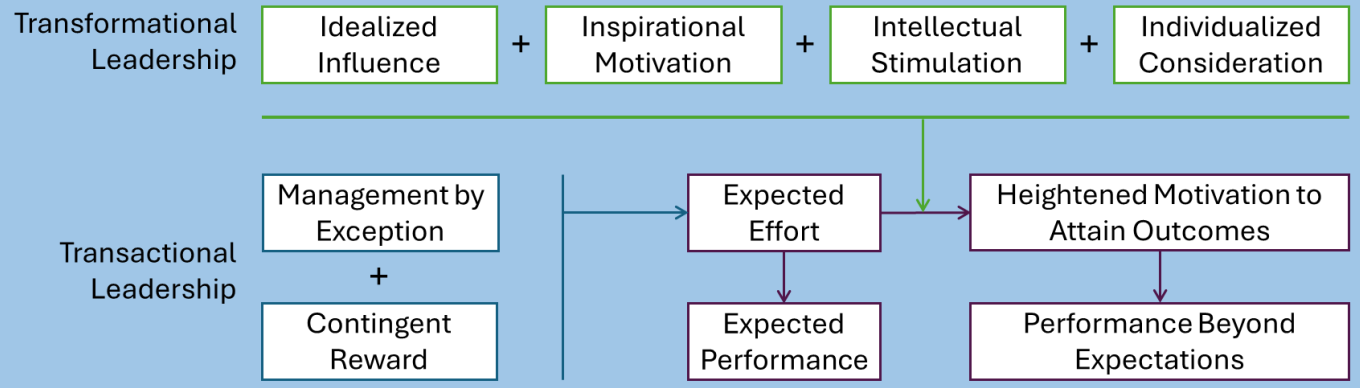
The transformational leader engages with others “in such a way that leaders and followers raise one another to higher levels of motivation and morality,” where leaders “throw themselves into a relationship with followers who will feel ‘elevated’” (Burns, 1998).



Transformation leadership focuses on improvement and innovation.

Bass Transformational Leadership Model

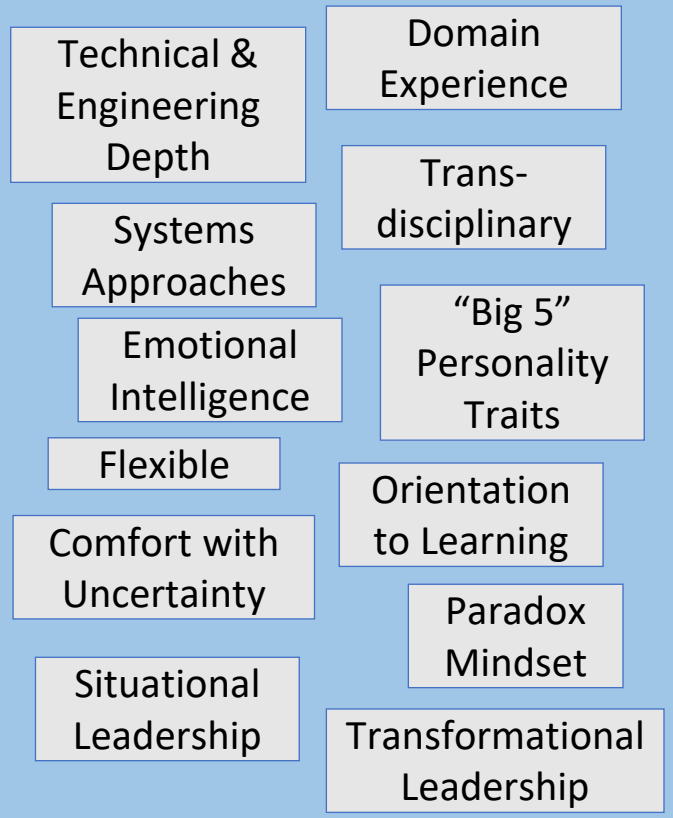
While transformational leadership motivates and inspires followers, transactional leadership is more focused on "exchanges" between leader and follower in terms of work tasks, penalties, and rewards. Both are important.



Aarons, G.A. (2006). "Transformational and transactional leadership: association with attitudes toward evidence-based practice." *Psychiatr Serv*. 2006 Aug; 57(8):1162-9.

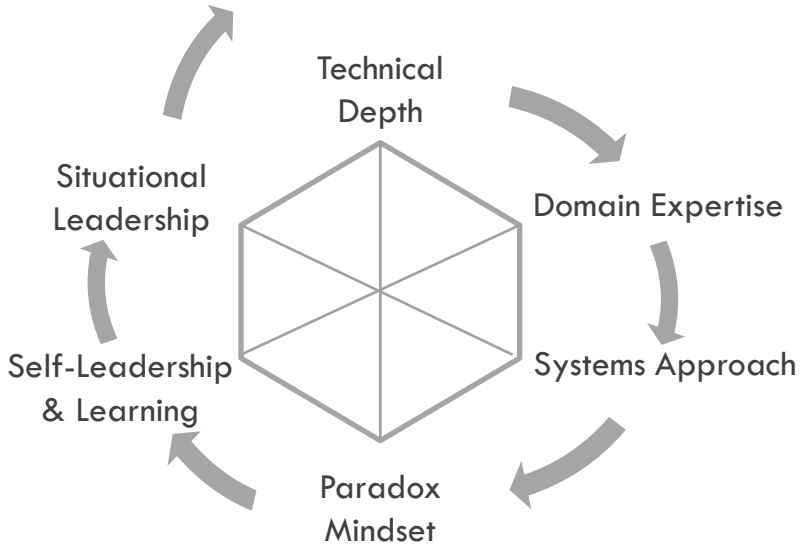
Megaproject Leader Development

- Success on smaller-scale simpler projects is not a good predictor for success on large-scale complex projects.
- Most organizations select megaproject leaders based on their performance on considerably smaller projects.
- How can we improve the selection of individuals for these critical roles?



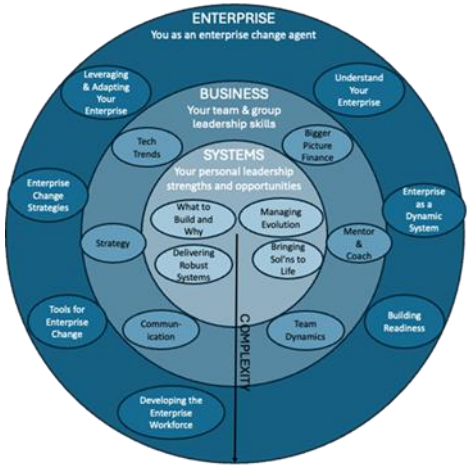
Megaproject Leader Development – Early Career

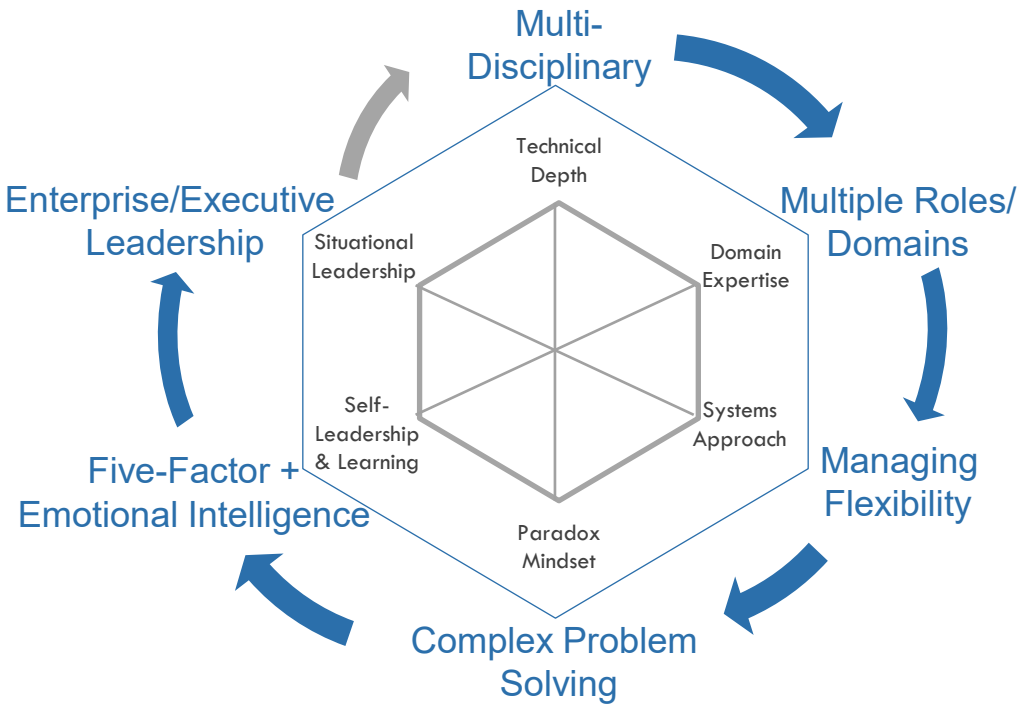
https://emp.helix-se.org/



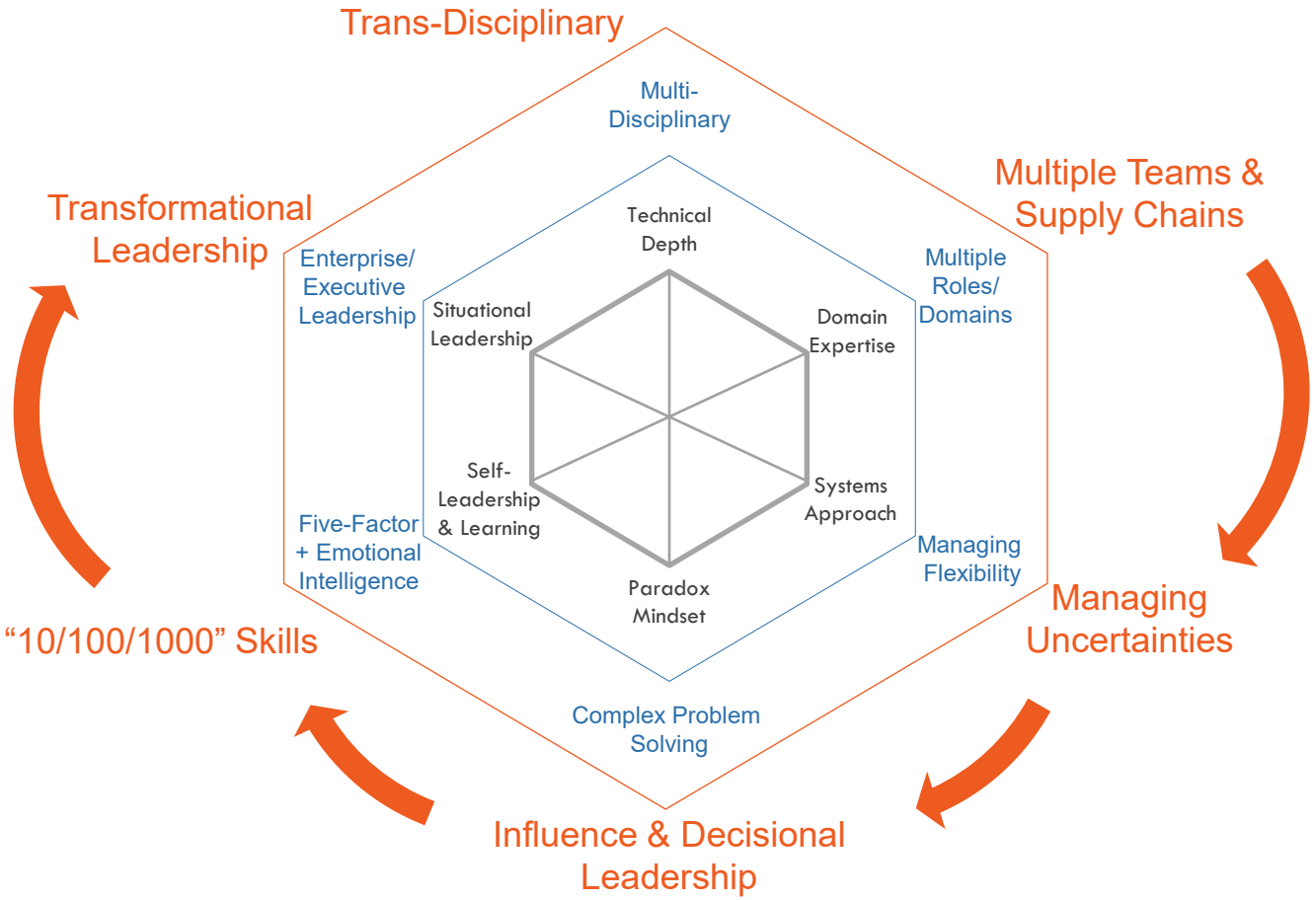
Megaproject Leader Development – Expanding Career

https://www.dau.edu/library/damag/may-june2019/growing-technical-professionals





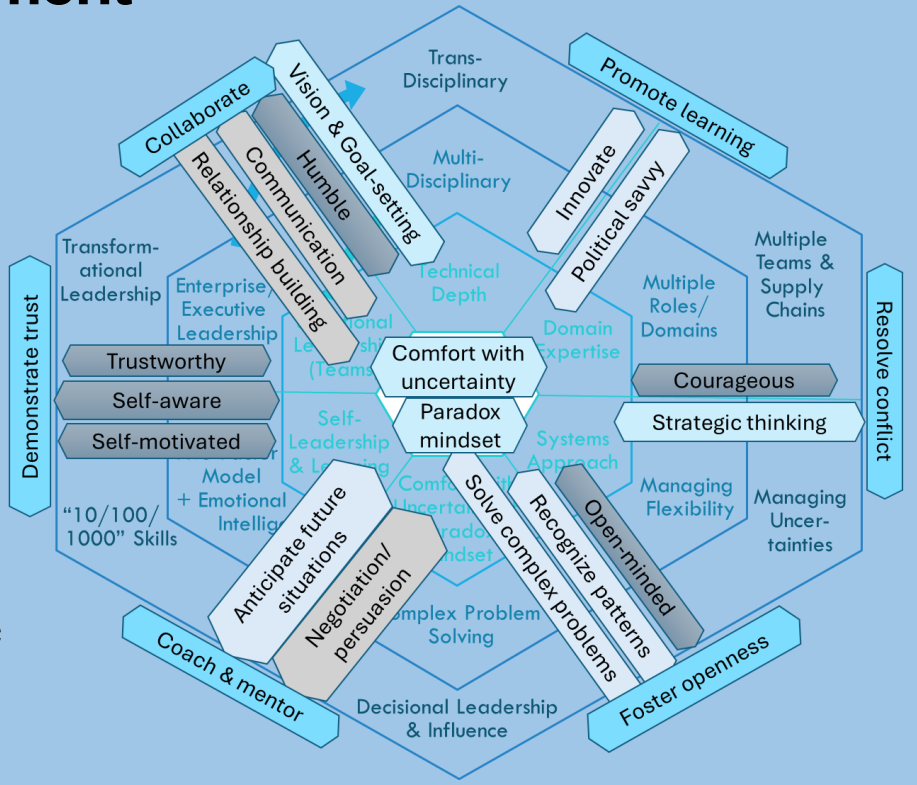
Megaproject Leader Development – Accomplished



Megaproject Leader Development

- Successful megaproject leaders are characterized not only by their domain expertise (often in engineering) but also by their capacity for self-awareness, openness, and a paradox mindset.

- Organizations should focus on these competencies when selecting and developing megaproject leaders, moving beyond conventional criteria that emphasize experience in smaller projects.



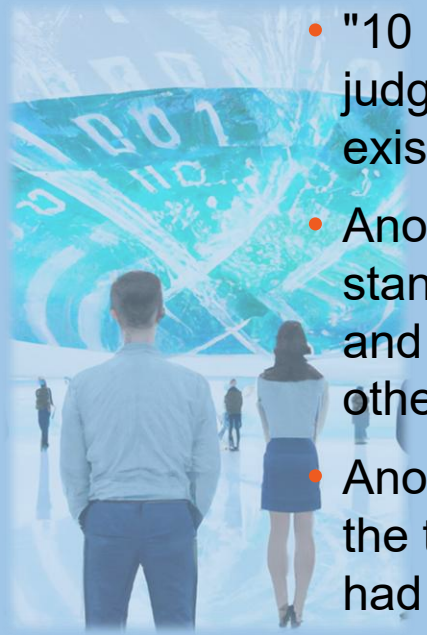
Megaproject Leadership Teams

No single human can have all required competencies – an effective **TEAM** is required

Needed variety of skills can only be combined into an effective team if **everyone** has adequate proficiency in teaming and interpersonal skills.

Successful Megaprojects choose leaders with megaproject skills

10/100/1000 rule from the Heathrow T5 megaproject:



- "10 senior leaders whose personal presence, vision and good judgement put the project on a course for success, often challenging existing industry norms.
- Another 100 leaders who by making critical differences, taking brave stands, interpreting new ideas and frameworks, leading by example, and ultimately creating an operating environment that enabled others to be successful.
- Another 1000 leaders who given that context were able to swim with the tide and do their leadership role in a demanding workplace that had little space for error."

Doherty, S. (2008). *Heathrow's T5: History in the Making*. West Sussex, England: John Wiley & Sons.

DAU quarterly webinars

Full Report

35th Annual INCOSE international symposium

hybrid event

Ottawa, Canada
July 26 - 31, 2025

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