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# Using Force-Field Analysis as Part of Systems Engineering Strategy to Achieve Goals

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# Systems Engineering and Strategy

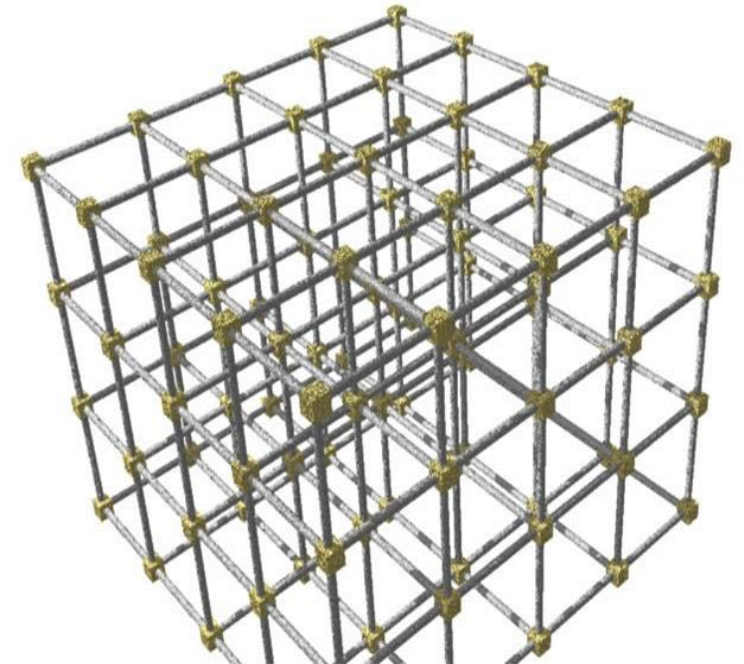
- Technical and business concerns
- Plays a strategic role
- Contributes to sustained competitive advantage



# Systems Engineering Strategy and Framework



- Systems Engineering Strategy: “Any application of strategy applied to systems engineering” [Smartt and Ferreira, 2011, p. 2]
- State transition-based
- Classes and attributes [Smartt and Ferreira, 2012]
  - The Organization
  - The Environment
  - The Product or Service Set Offered
  - Systems Engineering Processes



Systems engineering needs more systematic methods to achieve goals.



# Roadmap for this Paper

- ① Describe goals that work
- ② Explain a way to plan against those goals
- ③ Apply to an example



Whole Goals and Force-Field Analysis

# Goals

- Strategy presupposes a goal
- Challenges lead to higher performance [Locke et al., 1981]
- Whole Goals
  - Unambiguous and verifiable
  - Include restrictions – no side effects
- Presentation focus – achieving SE  
Whole Goals using FFA





# Why FFA?

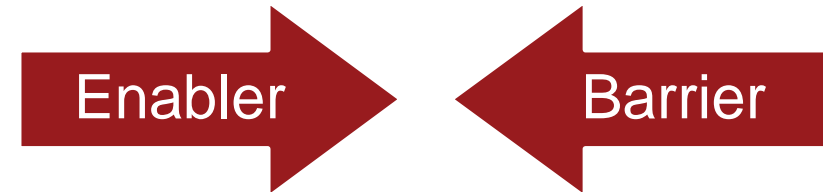
- Identifies what needs to get done to achieve goals
- Can help dislodge from unwanted equilibrium
- Flexible and scalable:

Example Personal Goals	Example Organization Goals
Kids earning better grades	Diversifying customer base
Attaining healthier body weight	Retaining employees
Saving more money for retirement	Planning succession in leadership



# Forces and Force Fields

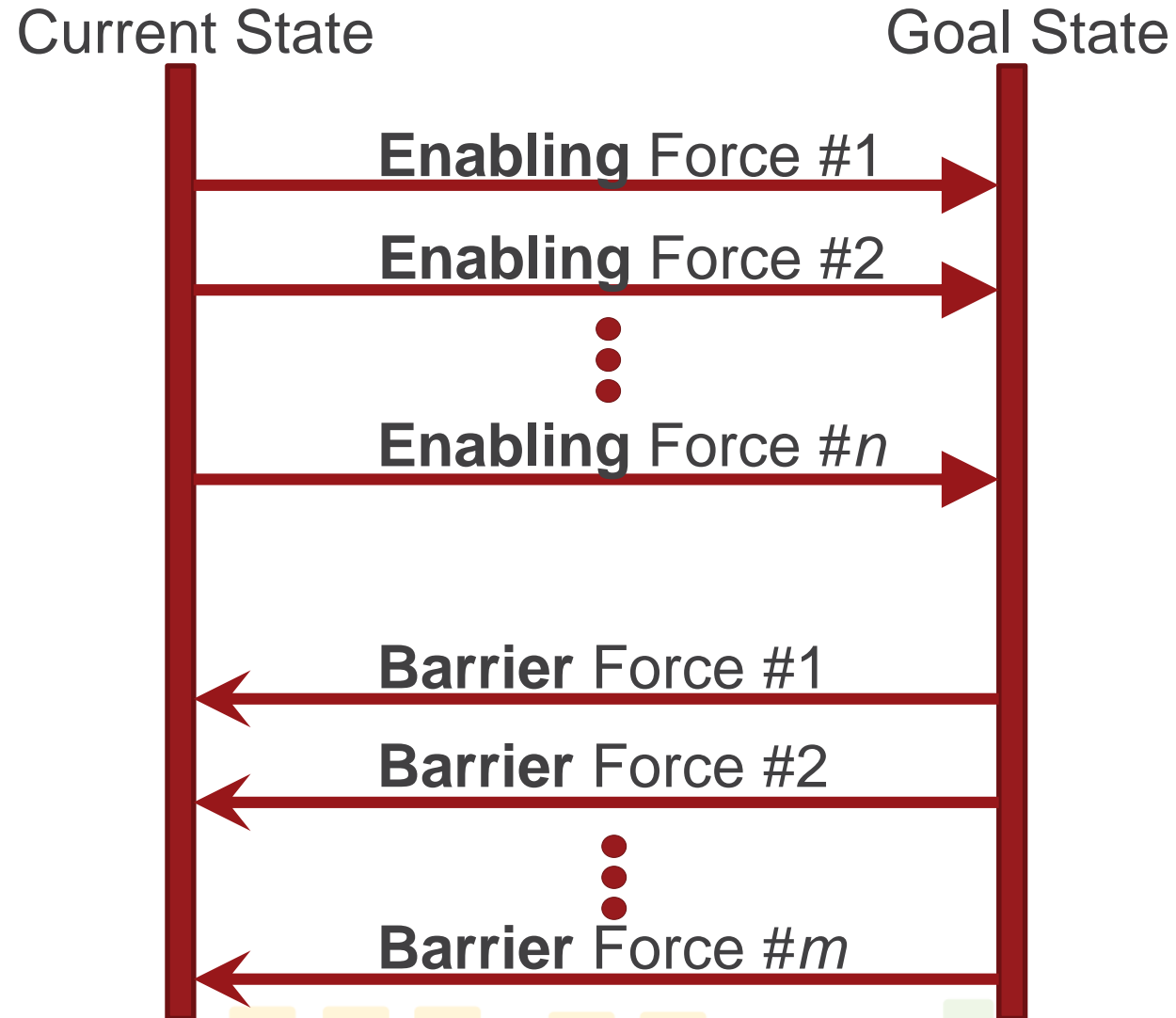
- Force is a vector in physics
- Sum of all forces = force field
- Force in FFA: “any influence acting in an organization such that the organization’s state is changed by that factor” [Schwerling, 2003]
- Types of Forces:
  - “Enabling forces” or “Enablers”
  - “Barrier forces” or “Barriers”







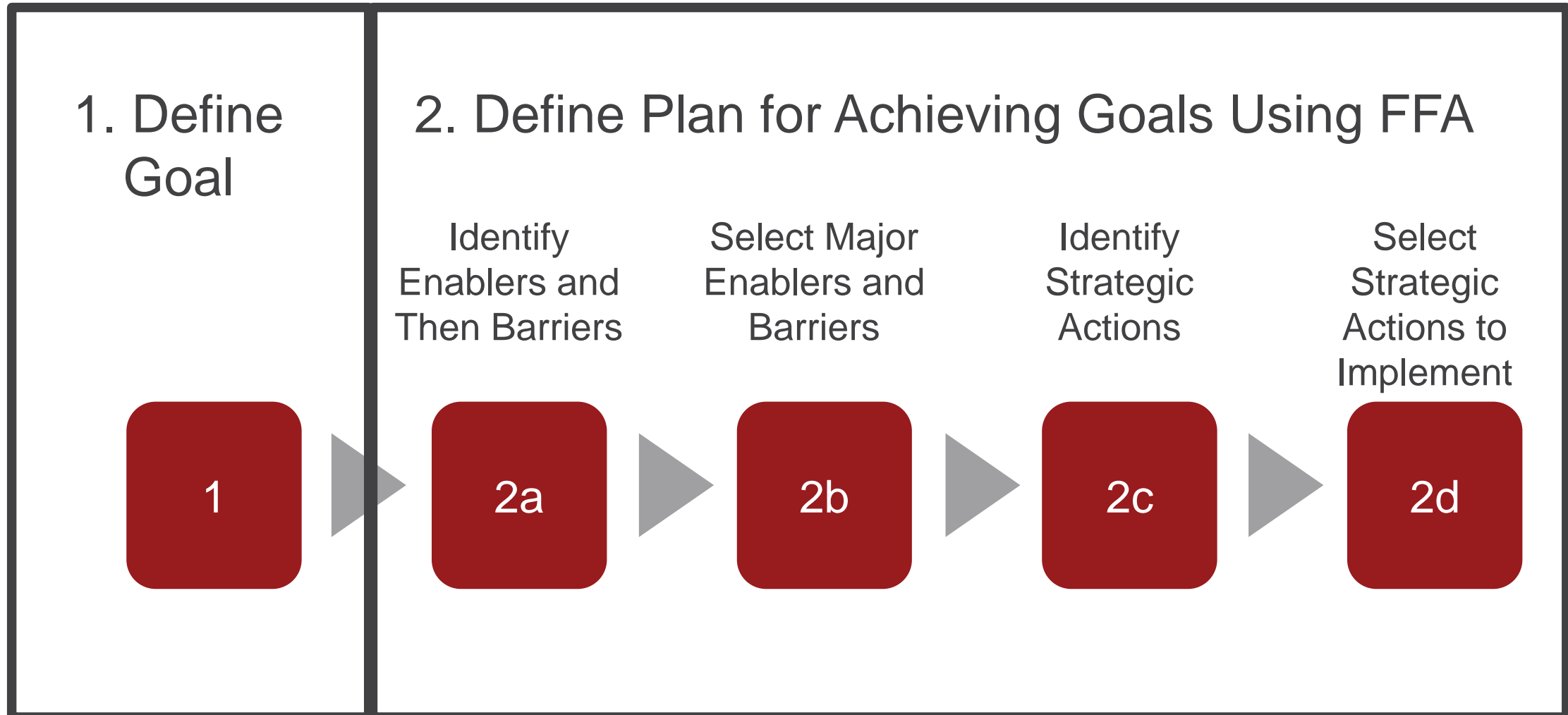
# Generic Conceptual Model of FFA







# FFA Steps and Recommendations





# Step 1: Define Goal

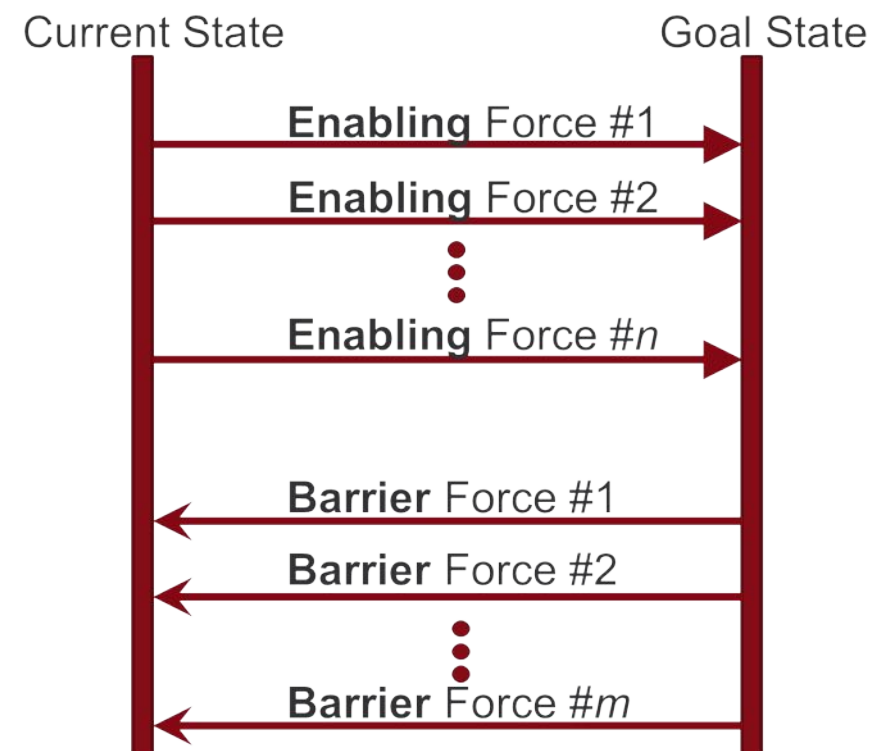
- **Description:** Define the goal to achieve, including non-ambiguous and verifiable criteria for achieving the goal as well as restrictions.
- **Recommendations:**
  - Work with small, senior group (e.g., management)
  - Appoint a facilitator
  - Facilitator and senior management
    - Shape and fully define the goal
    - Define restrictions





# Step 2a: Identify Barriers and Enablers

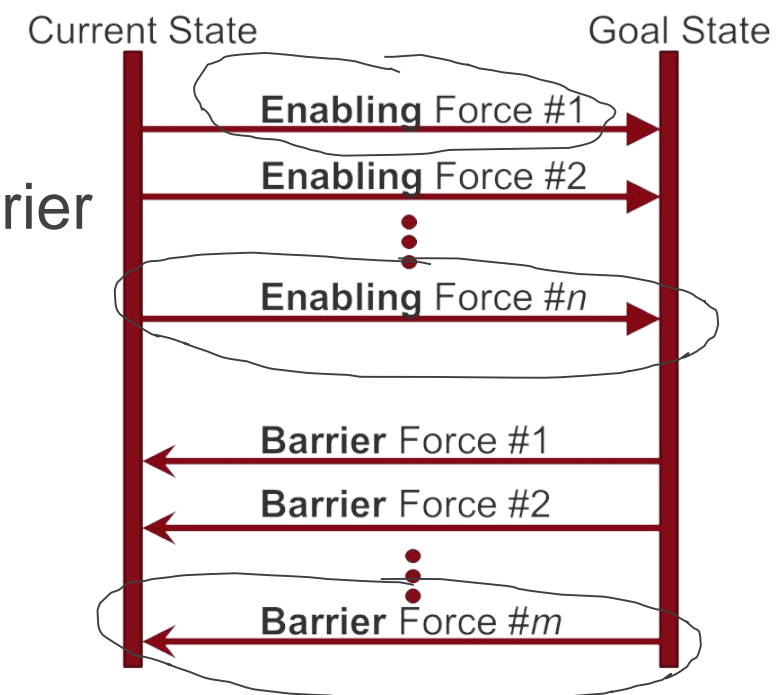
- **Description:**
  - Document enabling forces
  - Document barrier forces
- **Recommendations:**
  - Everyone contributes  $\geq$  one enabler
  - Compile master list of enablers
  - Consolidate similar enablers
  - Define and revise until clear
  - Repeat with barriers





# Step 2b: Select Major Barriers or Enablers

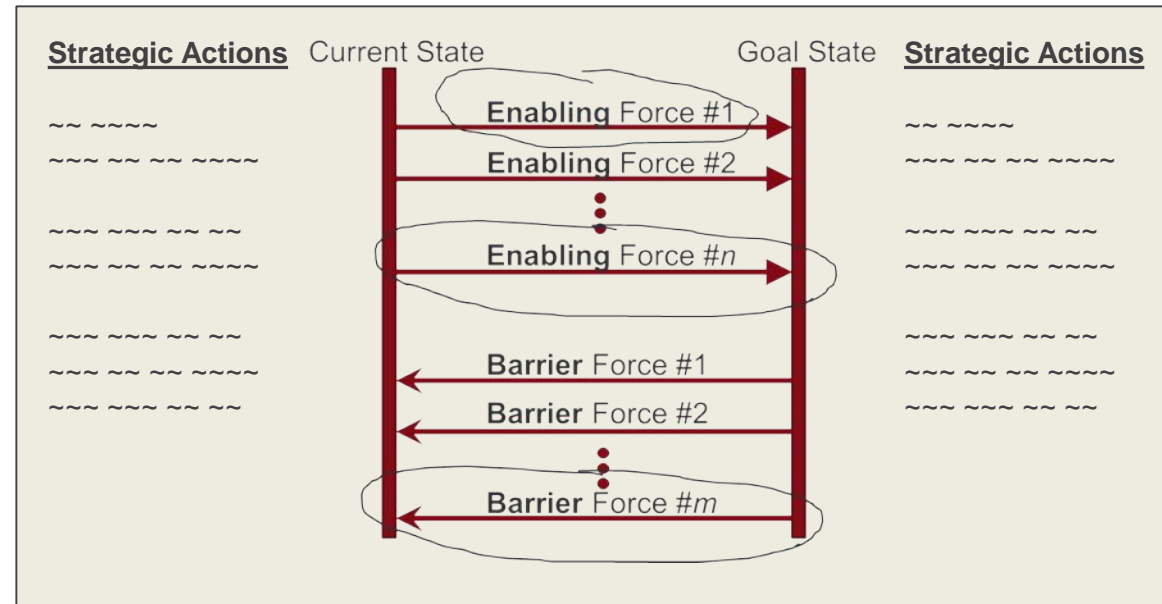
- **Description:** Select the top few enablers and barriers to focus on
- **Recommendations:**
  - Everyone nominates  $\geq$  one enabler and  $\geq$  one barrier
  - Chose enablers and barriers with a major impact
  - Don't be intimidated by barriers
  - Consider weighted voting [Mindiply, 2017]





# Step 2c: Identify Strategic Actions

- **Description:** For subset selected in 2b, determine what could be done to leverage enablers or overcome barriers
- **Recommendations:**
  - Repeat process in 2a
  - Divide and conquer
  - Consolidate and refine





# Step 2d: Select Strategic Actions

- **Description:** Select a few actions organization should focus on
- **Recommendations:**
  - Frame as cost/benefit
  - Repeat voting technique
  - Have senior leader make decision



# FFA and Systems Engineering

- Helps identify options
- Appears in literature for specific applications [Mesla, 2009; Santerelli, 2008]
- Systems Engineering Strategy framework
  - Prompting technique for brainstorming
  - Check-list
- Paper provides more general guidance





# Examples - FFA in Systems Engineering

- Maintaining up-to-date documentation after major maintenance or upgrade event
- Quickly growing SE knowledge in junior engineers
- Deciding whether and how to evolve to using model based systems engineering (MBSE) to perform systems engineering



# MBSE

- Formalized application of modeling to support SE processing
- Three pillars according to Delligati [2014]:
  - Modeling language
  - Modeling methods
  - Modeling tools
- SysML is a key language in MBSE



# Challenges of MBSE Adoption

- “Cultural change” [Friedenthal, 2009]
- Perspective many SEs do not have
- Even modelers must be trained
- Usually requires specialized software:
  - Expensive
  - Steep learning curve
  - Hard to administer and maintain software

Adopting MBSE is a challenge for an organization and must be done so with care.

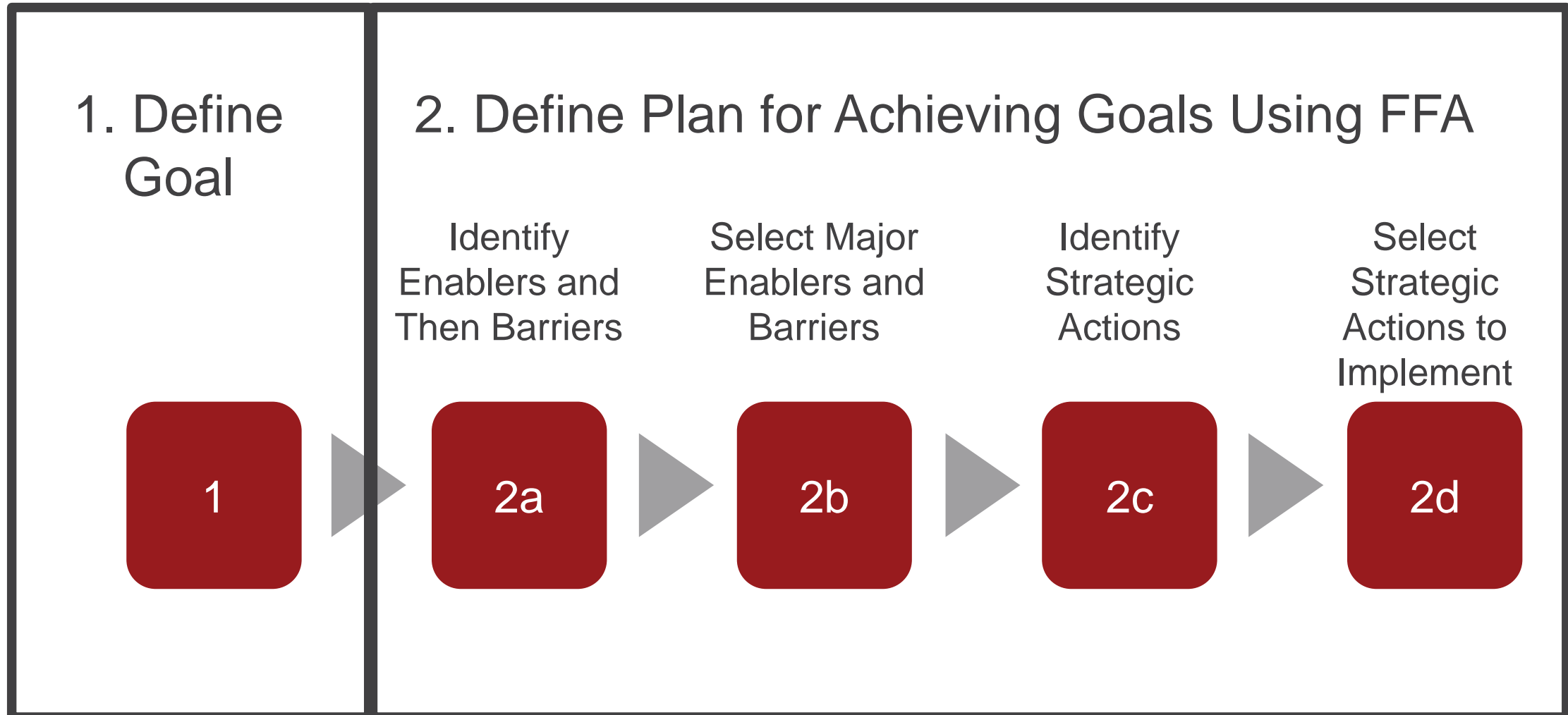


# Example Scenario

- Director of SE wishes to make informed decision about whether she will mandate use SysML
- To be avoided:
  - Prematurely institutionalizing SysML
  - Delay institutionalization too long
- Strategy: use SysML on a prototype effort as a pilot



# FFA Steps and Recommendations





# Step 1: Define Goal

- Wish to make an informed decision
- Looking for a serious attempt, but not jeopardize the pilot project

Whole Goal Statement: “Enable the director of systems engineering to determine whether to mandate the use of SysML in the organizations’ systems engineering process tailoring guidelines for projects in time for the next iteration of the tailoring guidelines.”

Don’t forget restrictions!



# Restrictions

- (a) Must try out SysML on a pilot project
- (b) Must expend sufficient funds for adequate rigor
- (c) Must not imperil pilot project because of added costs and schedule
- (d) Must use SysML tools
- (e) Must train at least 4 pilot project participants on SysML

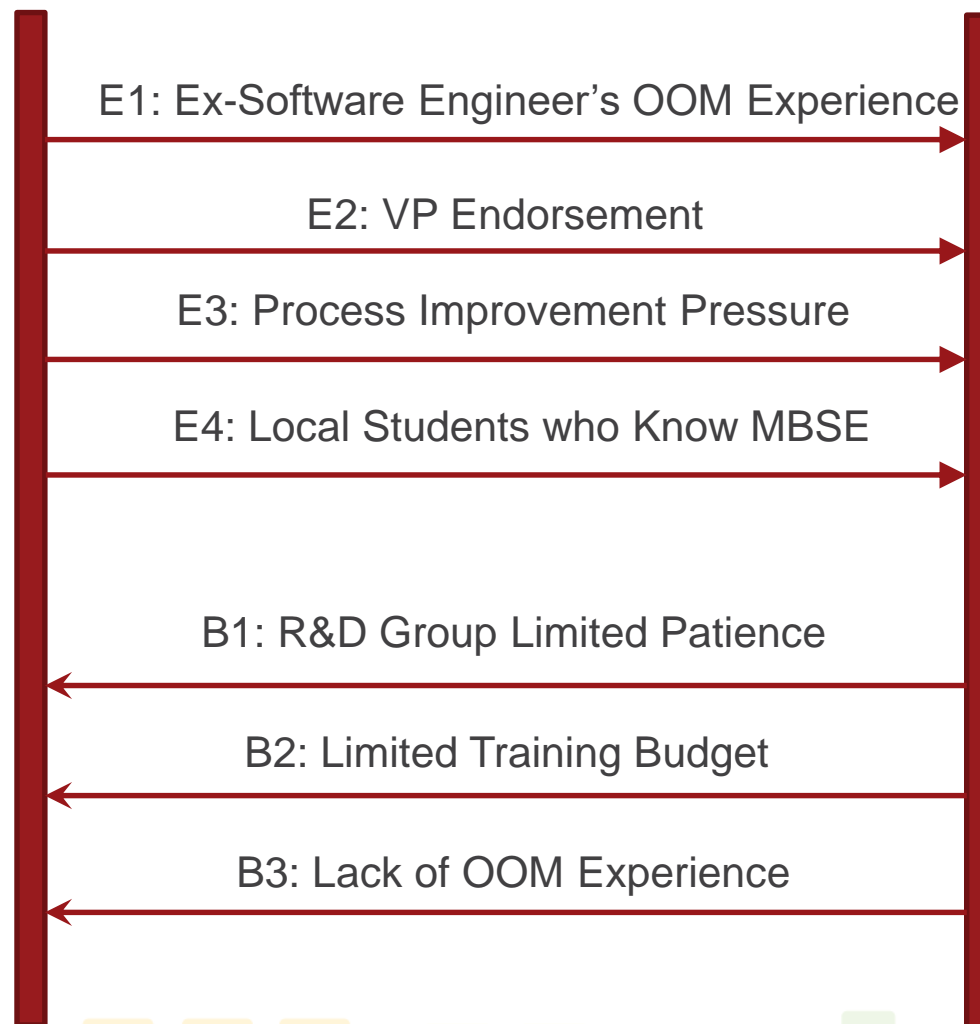




# Step 2a: Identify Barriers and Enablers

Current State

Goal State





# Step 2b: Select Major Barriers or Enablers

Current State

Goal State

**E1: Ex-Software Engineer's OOM Experience**

**E2: VP Endorsement**

E3: Process Improvement Pressure

**E4: Local Students who Know MBSE**

**B1: R&D Group Limited Patience**

**B2: Limited Training Budget**

B3: Lack of OOM Experience

So what?  
Doesn't  
really help.

So what? Use the  
people who do  
have OOM  
experience



# Step 2c: Identify Strategic Actions

Enabler/Barrier	Possible Strategic Actions
E1: Ex-Software Engineer's OOM Experience	<ul style="list-style-type: none"> <li>• Include two people with OOM experience</li> </ul>
E2: VP Endorsement	<ul style="list-style-type: none"> <li>• Use leverage to get best people</li> <li>• Request additional funding</li> </ul>
E4: Local Students who Know MBSE	<ul style="list-style-type: none"> <li>• Establish pipeline for recruiting students</li> <li>• Work to align SE curricula with organization's skill needs</li> </ul>
B1: R&D Group Limited Patience	<ul style="list-style-type: none"> <li>• Get technology SMEs to buy into SysML</li> </ul>
B2: Limited Training Budget	<ul style="list-style-type: none"> <li>• Request employees contribute some of their own time, but select training that leads to a certification</li> <li>• Offer flexible scheduling</li> </ul>



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# Parting Thoughts

- FFA powerful, systematic, and scalable
- Use FFA in systems engineering
- Applying FFA to a hard problem is hard work
- Allot time, resources and mental energy



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