Applying Theory of Constraints Tools to Focus Lean Development

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Introduction

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Boeing Engineering Analysis & Integration Team (AIT) in Wichita Kansas, where he is responsible for Lean support of Lean+ 10X and process improvement projects across a variety of Engineering disciplines. Tim is Theory of Constraints International Certification Organization (TOCICO) certified in the Thinking Process tools, a Boeing Six Sigma Black Belt and heads the Wichita site Six Sigma Steering Committee. Tim has a B.S. in Industrial Engineering from the University of Nebraska and an M.B.A. in Operations Management from National University. Tim has over 25 years of Aerospace experience with General Dynamics, Raytheon and Boeing. Tim has been published and a presenter at the 1999 AEROFAST conference. Tim received an Institute of Industrial Engineers process improvement award for a Statistical Process Control project he implemented to reduce office process flow time.

Theory of Constraints (TOC) Definition

TOC is a management philosophy introduced by Dr. Eliyahu M. Goldratt in his 1984 book *The Goal*, that is geared to help organizations continually achieve their goal. Based upon the contention that any manageable system is limited in achieving more of its goal by a small number of constraints (& that there is always at least one). The TOC process seeks to identify the constraint and restructure the rest of the organization around it, through the use of the Five Focusing Steps.

Key Assumption

The underlying assumption of TOC is that organizations can be measured and controlled by variations on three measures:

- **Throughput** is money (or goal units) generated through sales.
- **Inventory** is money the system invests in order to sell its goods and services.
- **Operating Expense** is all the money the system spends in order to turn inventory into throughput.

Standing on the Shoulder's of Giants

- **Theory of Constraints International Certification Organization**

www.tocico.org

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Eliyahu M. Goldratt

The Goal.
It's not Luck.
Critical Chain
Necessary but not Sufficient.
The Choice
Isn't it obvious

***Its Not Luck*, Eli Goldratt, 1997**

This textbook /novel introduces the Thinking Processes and shows their application of the Thinking Process in many different environments

***The Logical Thinking Process: A Systems Approach to Complex Problem Solving*, H. William Dettmer, 2007**

This is an excellent Theory of Constraints Handbook

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- **How to use the Thinking Process Tools**
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    - Evaporating Clouds to identify conflicts
    - Current Reality Tree
  - **What to Change to**
    - Strategic Future Reality Tree
  - **How to cause the Change**
    - Prerequisite Trees and Transition Trees
    - Strategy and Tactics Tree

Theory of Constraints Basic Facts

- **Every system is part of a larger system**
- **Every system has sub-systems**
- **A system is made up of individual elements that are linked in some interdependent fashion**
- **Within any complex system there is one constraint (or very few) of several possible types**
  - Every system has a limiting factor, else growing systems would soon explode
- **It is always possible to find the constraint and exploit it or improve it**

The Five Focusing Steps

0. What is the Goal

0.5 How to Measure Progress toward Goal

1. Find the System Constraint

2. Decide How to Exploit the Constraint

3. Subordinate everything else to the Constraint

4. Elevate the constraint

5. If the constraint moves, start over at Step 1

Constraints Management

- **In physical systems (machines, production, distribution, …) the constraint is relatively easy to find**
- **In non-physical systems (social systems, service organizations, interactions, relationships, self-governing, not-for-profit, creative groups, …) it is harder to find**
- **While we can often change our minds faster than changing equipment, getting EVERYONE to change their minds at the same time, is pretty hard**

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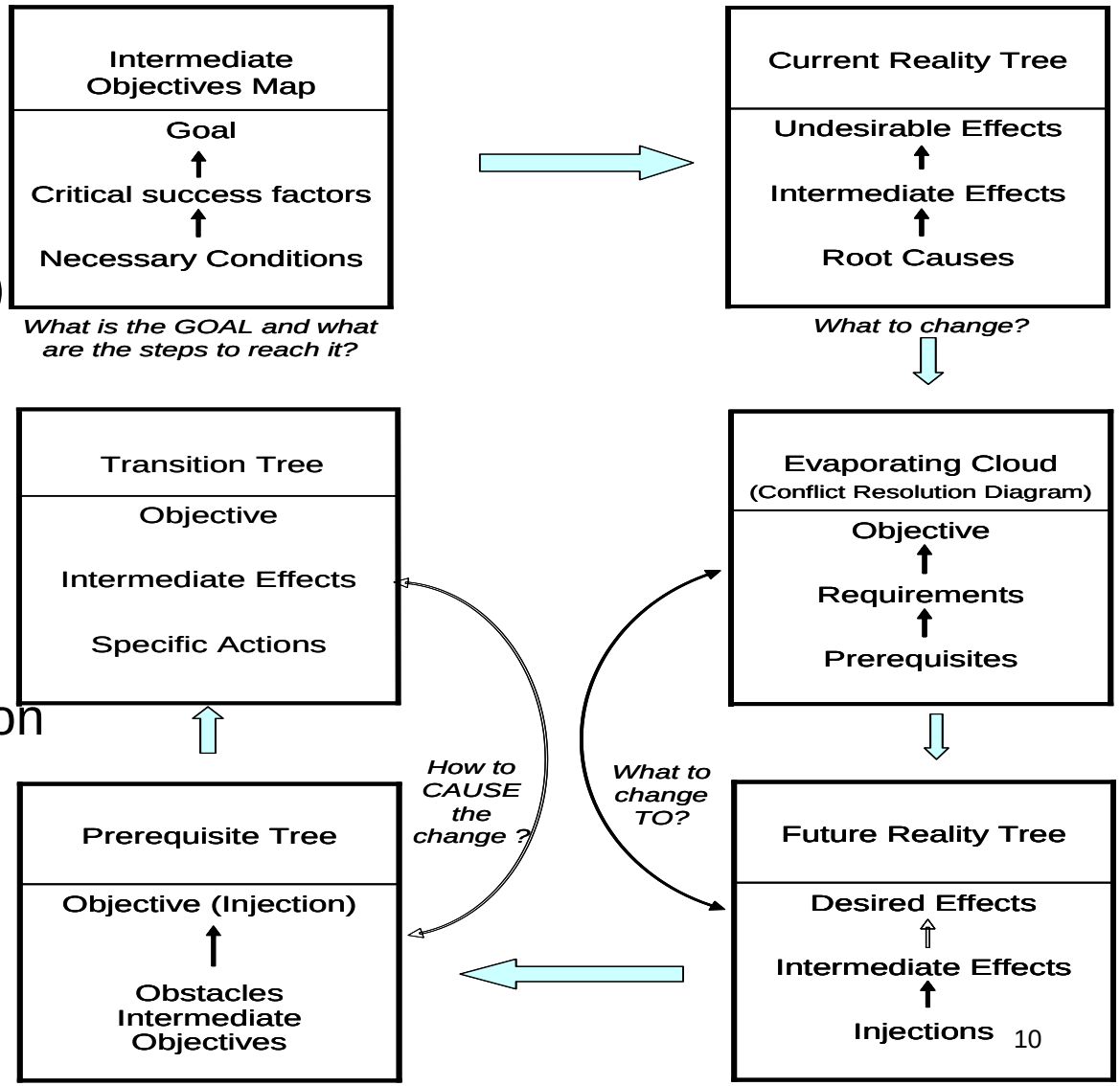
TOC Thinking Processes: Constructs

- Evaporating Clouds

(Conflict, 3 clouds, CCC)

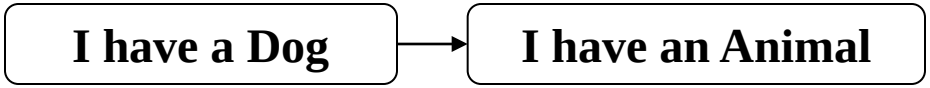
- Assumptions
- Undesirable Events (UDEs)
- Current Reality Tree (CRT)
- Injections on CCC
- Desirable Events
- Future Reality Tree (FRT)
- Negative Branch Reservation
- Prerequisite Tree (PRT)
- Transition Tree (TT)



Source: The Logical Thinking Process, H. William Dettmer, 2007

Different Logic Patterns

- Logic: There are two main types of logic: Sufficiency-Based logic and Necessary-Based Logic



- With sufficiency based logic, we read in the direction of the arrow and say IF A, THEN B, we mean, "It is sufficient that if A exists, then B exists." IF I have a dog, THEN I have an animal. Having a dog is sufficient to satisfy the conclusion that I have an animal. This is common sense
- With necessary based logic, we read against the arrow and say, In Order To C, I Must Have D. In Order To make a fire, I Must Have combustible material. This is also common sense. Can you have a fire without combustible material?

- These two different types of logic are often confused, but shouldn't be. One is forward thinking, the other is backwards thinking. They are Different
- IN ORDER TO have an animal I MUST HAVE a dog. Is that common sense? No, I could have a cat. IF I have combustible material THEN I have a fire. Is that common sense? No, there are other things necessary to have a fire. The categories of legitimate reservation make sure the logic is solid

source: Washington State University-2010

Alternating Logic Types

- The Theory of Constraints Thinking Processes use both necessary and sufficient logic. In examining the logic tools closely, you see the tools alternate the logic types. The CRT, FRT and TT use sufficiency based logic. The EC and PRT use necessary based logic. This clever alternating logic causes the final conclusion to not only be necessary but also sufficient--the solution will be the minimum set of required conditions to be sufficient to assure success.
- These two, common logic types each discover causality in different ways. By alternating them, we clarify and better understand. We recognize that all dogs are animals. And, we need heat and oxygen besides combustible material to create a fire. The use of both makes our thinking process robust, forgiving and reliable. Using them both will help you discover new knowledge.
- Some people claim necessary based logic is right brained and sufficiency based logic is left brained. Maybe getting both sides of the brain to work together will be a boon! Anyone can learn necessary based logic. It just takes practice.

source: Washington State University-2010

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Evaporating Clouds are Necessary-Based Logic

- Necessary based logic is the basis for the Evaporating Cloud (Conflict Resolution Diagram as Dettmer calls it). What are the necessary conditions to achieve the goals we desire? What are the prerequisites for the necessary conditions?
- The Evaporating Cloud is used to surface intuition, generally accepted assumptions, unspoken understanding, and established rules.
  - These areas (assumptions behind the necessary logic arrows) then become targets for challenge / change/ improvement.
  - The traditional assumptions limit the range of solutions to our problems.
  - If the traditional assumptions can be made invalid, then we have found a place where the necessary conditions no longer hold.
  - We call such a discovery, a breakthrough injection.
- The Evaporating Cloud is the most easily used logic tool. It can be used everyday to develop understanding, facilitate communication and resolve every-day conflict. Students of the Thinking Process should learn to create Evaporating Clouds in minutes. It is most better to resolve conflicts quickly, before they become chronic

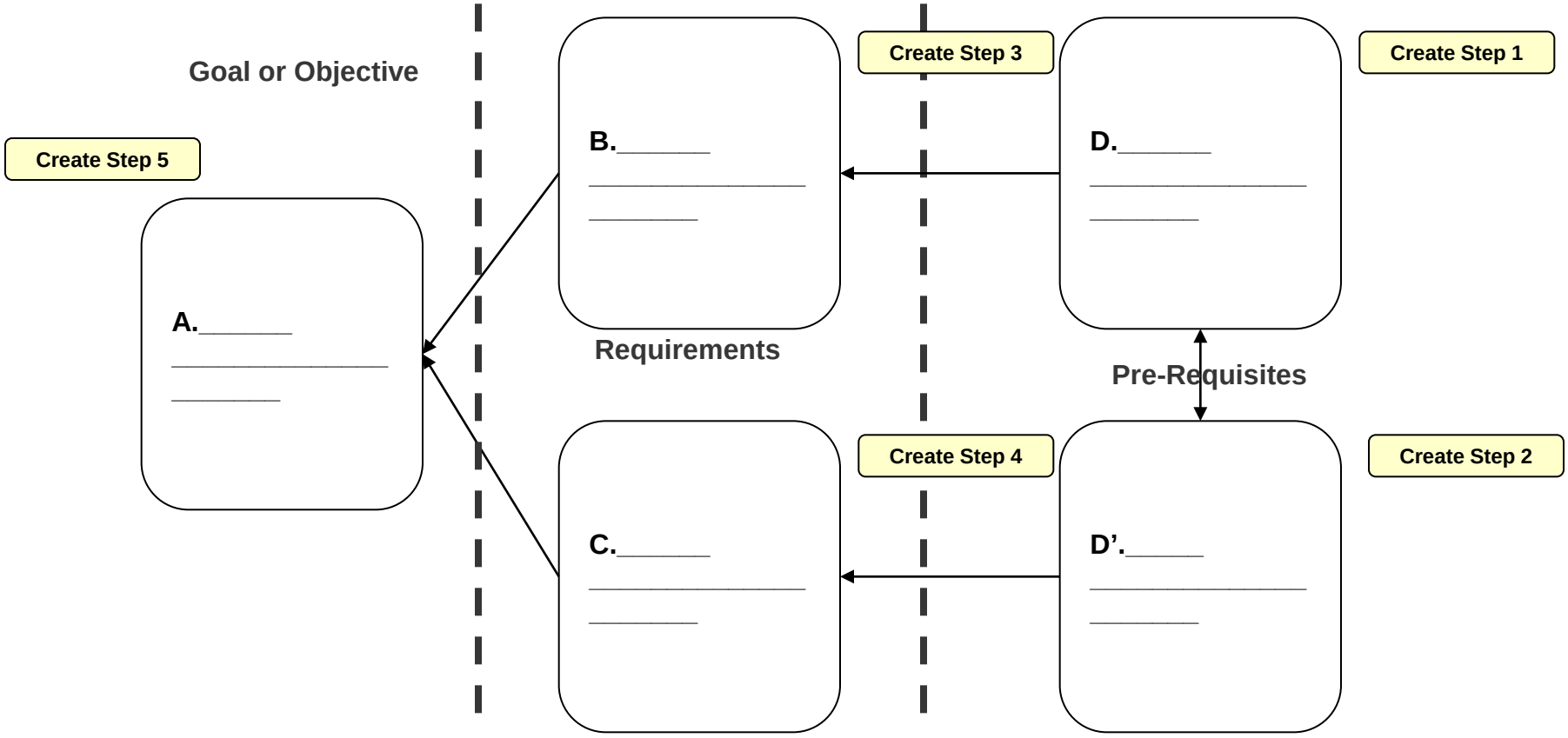
source: Washington State University-2010

Here is an Evaporating Cloud Worksheet

Story line: _____

_____

_____



source: Washington State University-2010

Guidelines for Creating and Evaporating Cloud

As soon as you recognize there is no room for an acceptable compromise (there is a breakdown in communication, the other side is becoming stubborn and illogical or our relationship is in jeopardy) take a break. During the break:

1. **Write down WHAT I WANT (D.)**

   You know this. You keep repeating it over and over out loud and in your thoughts. (Usually, this is an action or result of an action)

2. **Write down WHAT THE OTHER SIDE WANTS (D'.)**

   You know this. They keep repeating it over and over trying to convince you.

3. **Write down WHAT NEED I AM TRYING TO SATISFY. (B)**

   You may have to stop and think hard here. Why is it you NEED the thing you want?

4. **Write down WHAT NEED THE OTHER SIDE IS TRYING TO SATISFY. (C)**

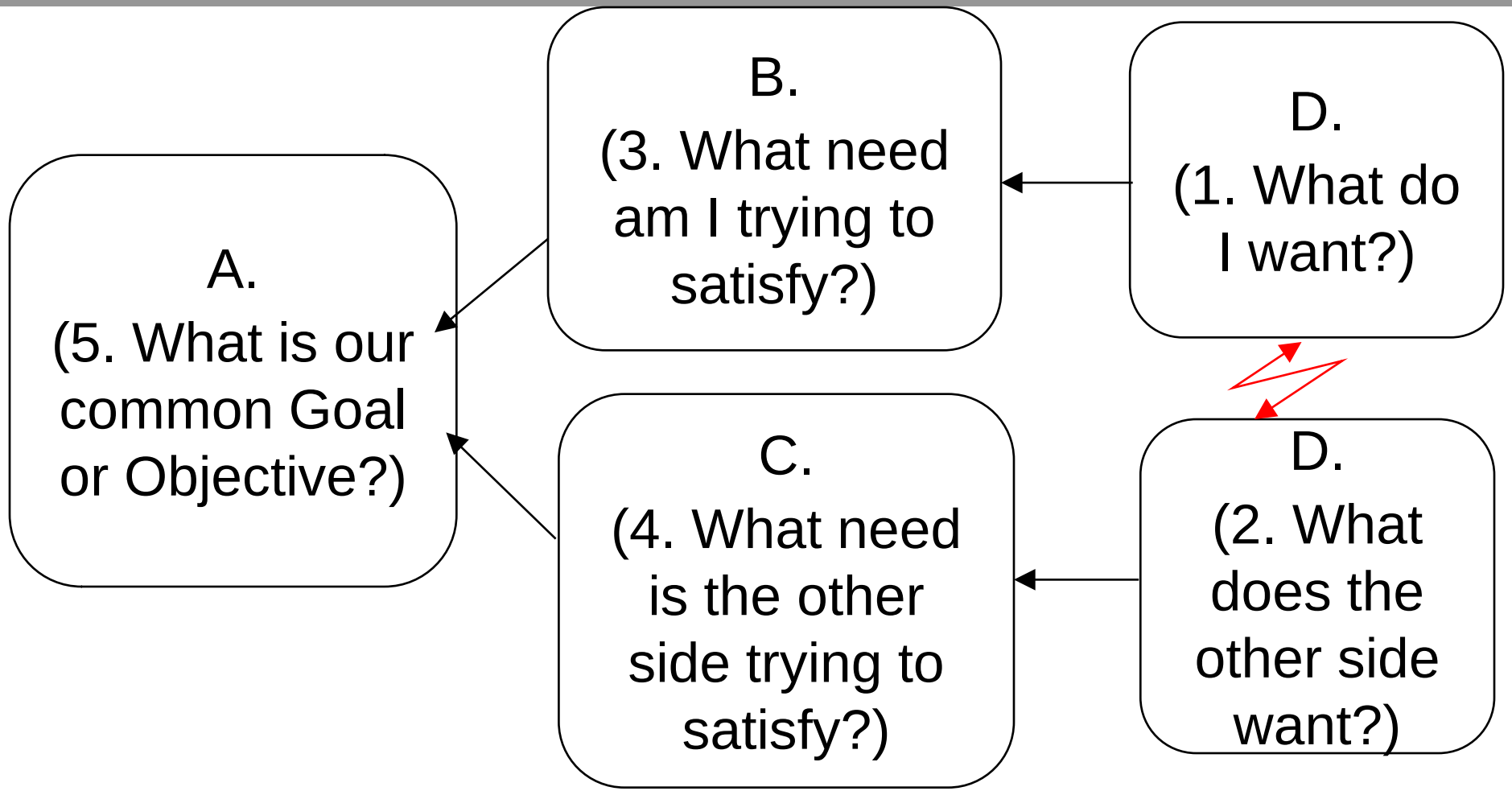
   If you don't know, you haven't been listening to the other side. Think! What was their justification for their desires? That was their need?

5. **Write down OUR COMMON OBJECTIVE. (A)**

   Yes, you have one. You are still talking! What is the reason you are still talking to this hard headed, obnoxious, uncooperative person on the other side? What do you both want to have? What goal do you both need to satisfy? Why is it you are trying so hard to convince the other side to cooperate?

source: Washington State University-2010

Creating the Evaporating Cloud



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Focusing Lean Support Group
Core Conflict Cloud

Story line: The company has limited resources to perform "Process Improvement" and support internal customer needs for Change and Improvement. These "change agents" are tasked with working with Employee Involvement Teams to create a culture of process improvement. There is an effort underway to explore TOC as an improvement tool.

Combine LEAN and TOC for fast, surgical results!

Assumptions
1. There is pressure to try something better than what we have been doing
2. Our customer has changing requirements
3. The customer wants products faster and cheaper
4. Difficult to schedule today what is going to occur more than 6 months in the future
5. Our project requirement are not all the same

Train TOC folks on how they can benefit from LEAN (to improve the difficult processes they find – in CCPM for sure – and other bottleneck areas).

Assumptions
1. Our current date driven scheduling causes us to have to do project rescheduling
2. There is pressure to try something better than what we have been doing
3. we need to improve our processes
4. TOC takes in to account delays and resources availability
5. TOC is a good way to create process that are adaptive

Dc.'
1. Take radical, unproven (to me), experimental procedures

Bc.
3 Do things that deliver significant results quickly

Use the Thinking Tools Process to establish priorities for Process Improvement Projects

Assumptions
1. We don't know where to focus resources
2. Implementing both concepts causes confusion
3. Lean and EI don't always deliver desired results
4. Not everyone knows TOC

Ac.
5 Dramatically improve our processes

Focus resources on where the highest savings are (largest improvement can be made – that contribute to Throughput immediately (or accelerate project management processes)

Cc.
4. Do mature, correct things that have proven to be very effective over time

Dc.
2. Use the best LEAN tools and techniques, EI (Employee Involvement)

Assumptions
1. We need to improve our processes
2. Stable processes makes jobs easier to manage
3. We know how to control stable process
4. If we change we might create an unstable process

Assumptions
1. Toyota like methods have been up to this point the company accepted method for continuous improvement.
2. Toyota is considered to be successful with their implementation of Lean Processes
3. The accepted site improvement methodology has been EI
4. It is easier to stay with the current culture
5. EI teams are easy to measure and control

Train Lean Facilitators on TOC

There is a method to create and maintain stable balanced processes (We become a fast, reliable source of expert knowledge and projects. We can pick and choose which, of many, contracts we will pursue. We are profitable. We can grow our capacity at a rate we choose.

Create meaningful improvement metrics associated with Increasing Value and decreasing Time

Find other ways to implement Employee Involvement (remove the obstacles to being fast and let the work itself be the reward)

In order to … *Objective*

We need to … *Requirement*

In order to…

We need to … *Prerequisite*

CLRs – Categories of Legitimate Reservation

- Are tools to rigorously evaluate and critique (scrutinize) logic statements in a non-threatening manner
- Ensure the logic is solid
- Help solidify intuition or emotion into solid cause-effect relationships
- Force the discovery new knowledge to correct logical errors
- The Categories of Legitimate Reservation are the tools to validate or invalidate any argument. They are very powerful when applied in a systematic way. They are the tools to discover the underlying assumptions.

source: Washington State University-2010

Categories of Legitimate Reservation

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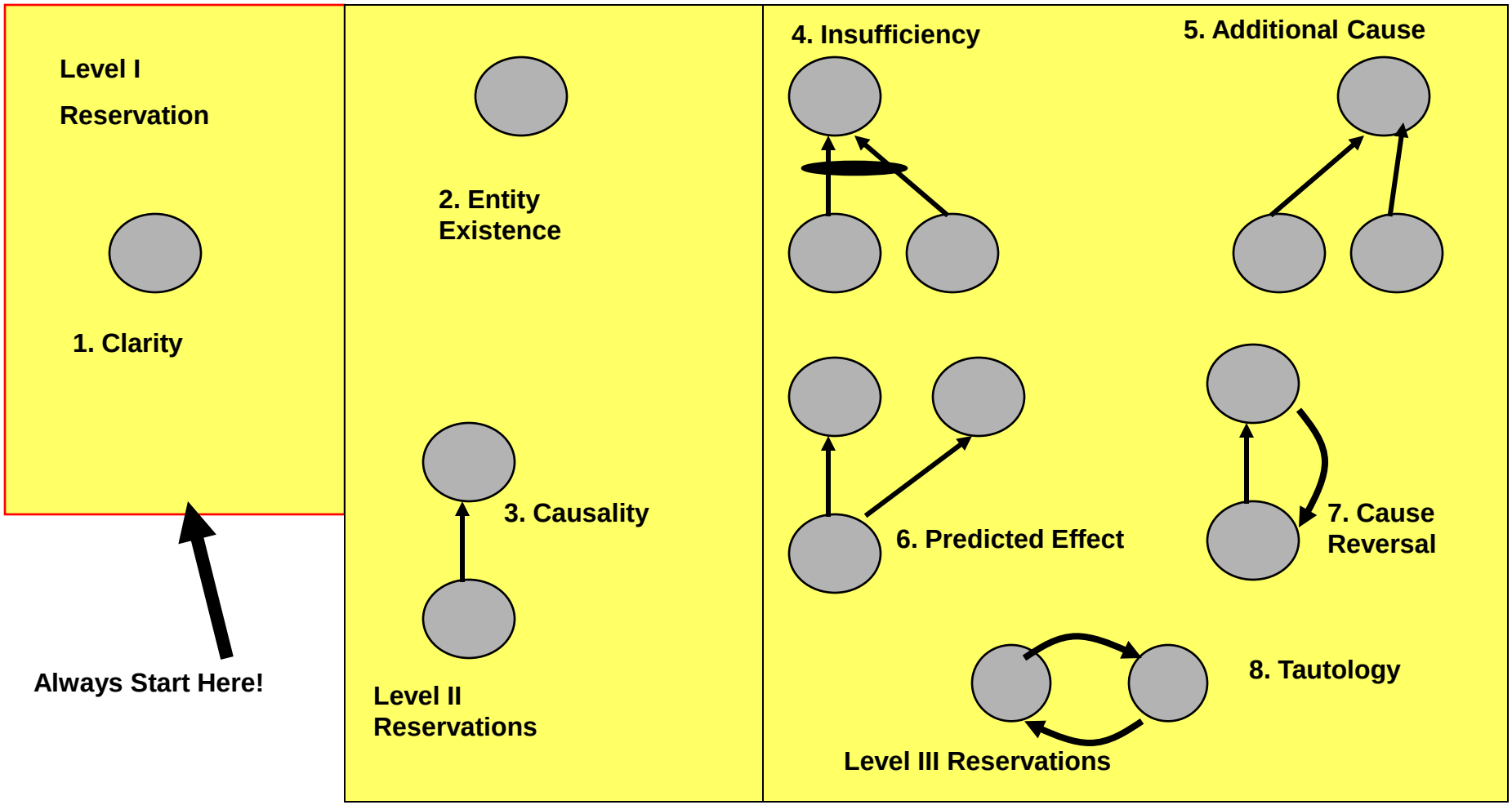

source: Washington State University-2010

Scrutiny!

- **What is Scrutiny?**
- **We want to examine each logical arrow according to eight logic rules (CLRs).**
- **Taken together with your intuition, they are sufficient to demonstrate the truth of your logical connections.**
- **Or, they will surface legitimate reservations about the logic.**
- **Anytime a reservation is surfaced and addressed, additional knowledge is gained. DISCOVERY!**
- **Use Scrutiny to gain deeper understanding/discovery.**
- **Use it on yourself and with others. Encourage them to scrutinize you!**

source: Washington State University-2010

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Creating a Current Reality Tree from UDE

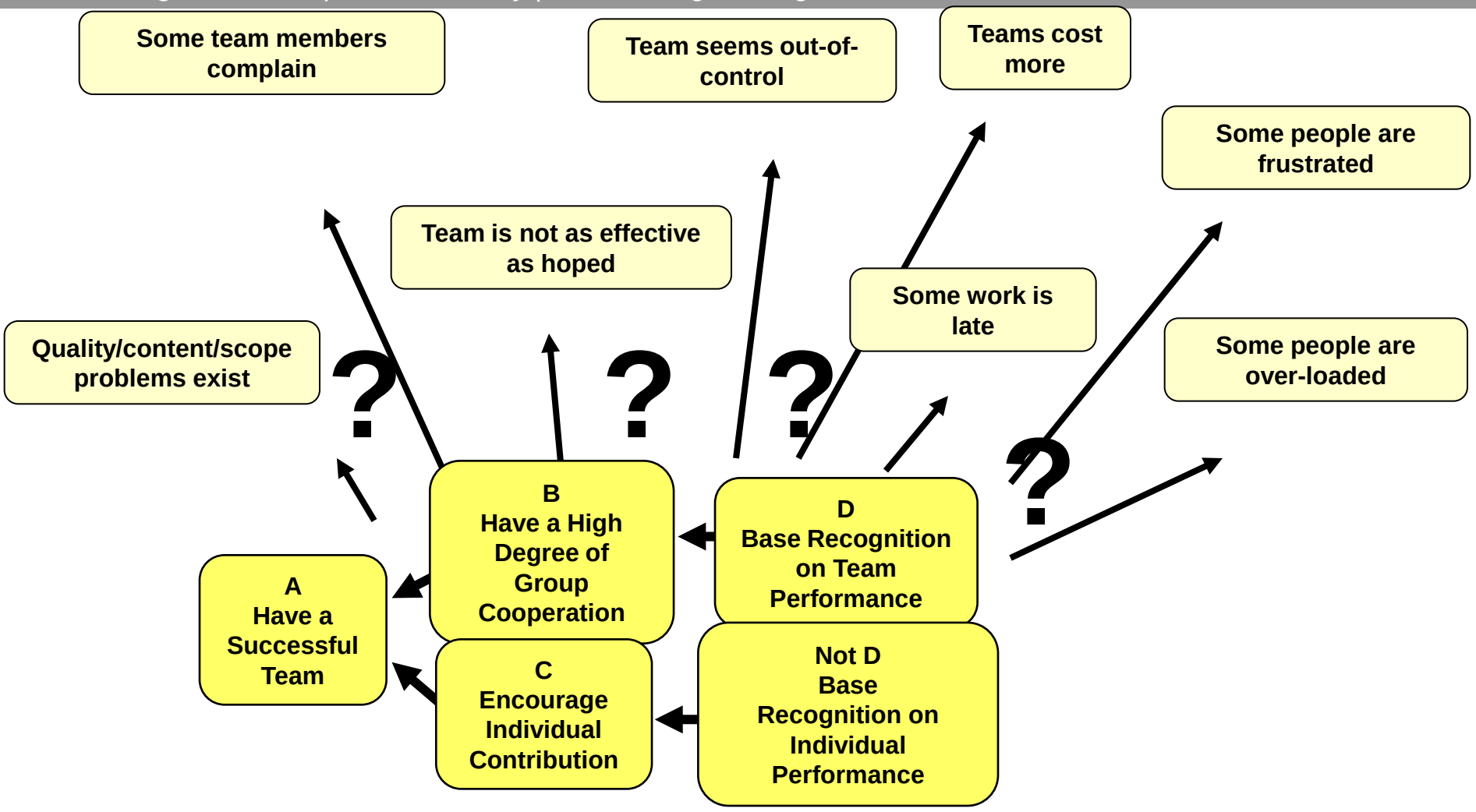
- **UDEs – Undesirable Effects**
- **Let's approach these UDEs and the whole world of Team Management by taking three different situations (one UDE clouds) and combining them.**
- **Development (or Design) / Business / Education**
- **Other areas would have worked just as well; these are good enough**

source: Washington State University-2010

UDEs of Lean Support Group

- The majority of BDS leadership has the perception that lean does not generate results.
- *Employee Involvement has not produced the results desired
- *Lean has not produced the results desired
- *Leadership is hesitant to apply lean to a business problem.
- *Lean results do not show up in EAC
- *Leadership feels leading Lean is not a valuable way to spend their time.
- *Leadership fears using Lean because of fear of not being able to proved the expected improved financials.
- *Lean facilitators are most comfortable with soft skills facilitation / training and not driving teams to achieve significant improvement fast
- *Lean facilitators are not comfortable not driving teams to achieve significant improvement fast.
- *Lean facilitators are conflict adverse..
- *Lean facilitators become ineffective when having to lead real change.
- *People are confused at which measure to follow
- *People are frustrated
- *People are not happy (satisfied) with their work
- *The site is not performing as well as it should
- * Lean facilitators are not sure which metrics to track and follow
- *There is general confusion about what the goals and objectives are
- *There is a general lack of focus and direction
- * Lean facilitators are not supporting all the needs of the customers
- *Employee Involvement is not capturing as much savings as possible
- *There is conflicting direction from matrix chain of command
- *There is lack of emphasis on improvements that impact the bottom line
- *There is confusion on which tools and techniques to use

Does this Conflict seem to CAUSE all the UDEs?



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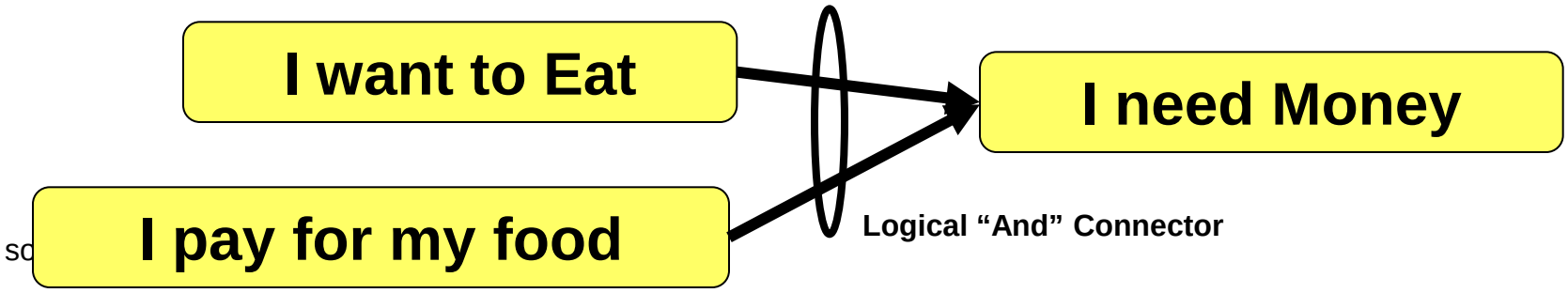
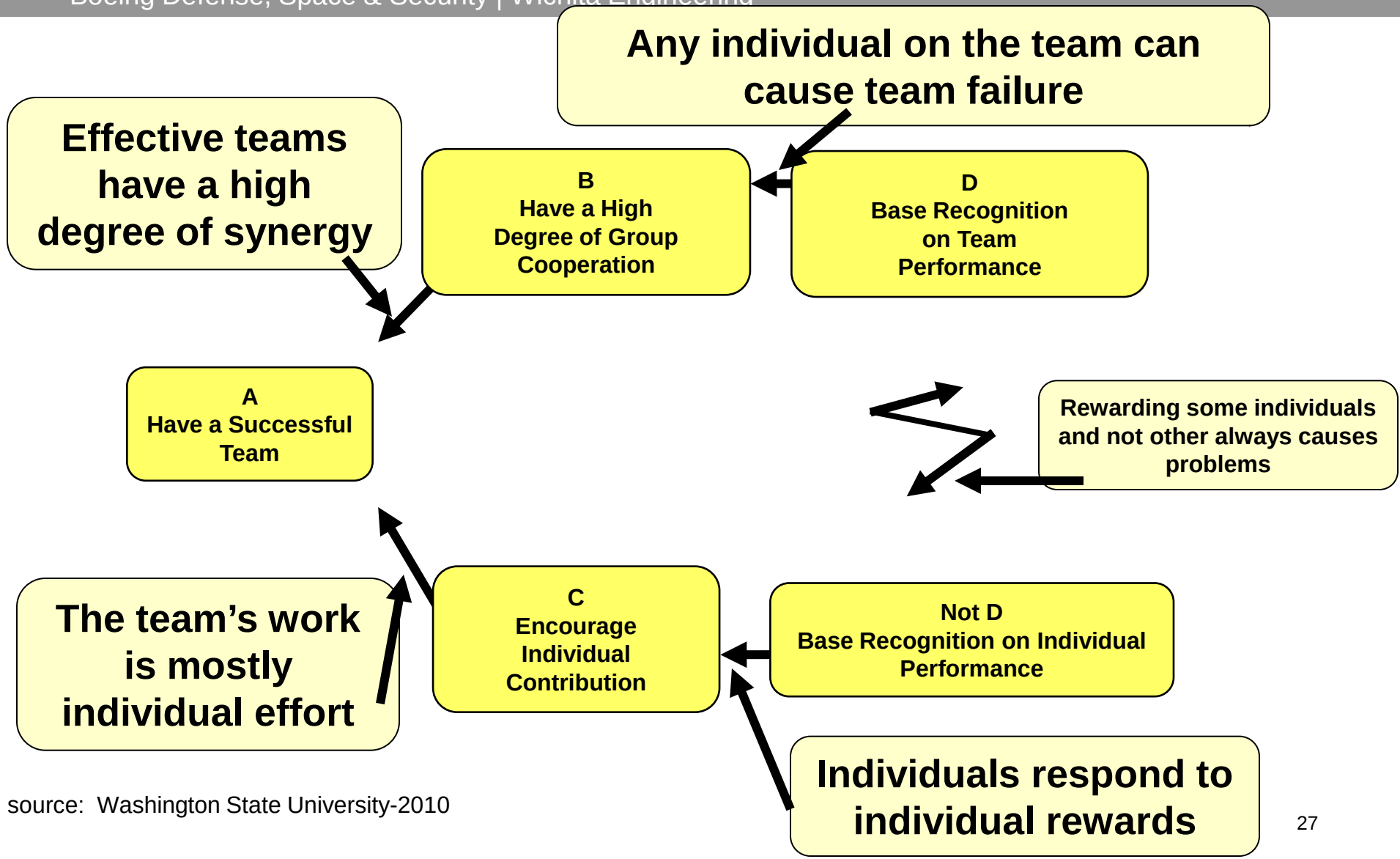
Behind Every Arrow, There is an Assumption

- **The assumption in Necessary Based logic was:**
  "In order to Eat, I must have Money Because I pay for my food."



- **The assumption in Sufficiency Based logic is the same but is structured slightly differently:**
  "If I want to eat, And I pay for my food, Then I need money."

Some Assumptions Behind the Arrows of the Core Conflict



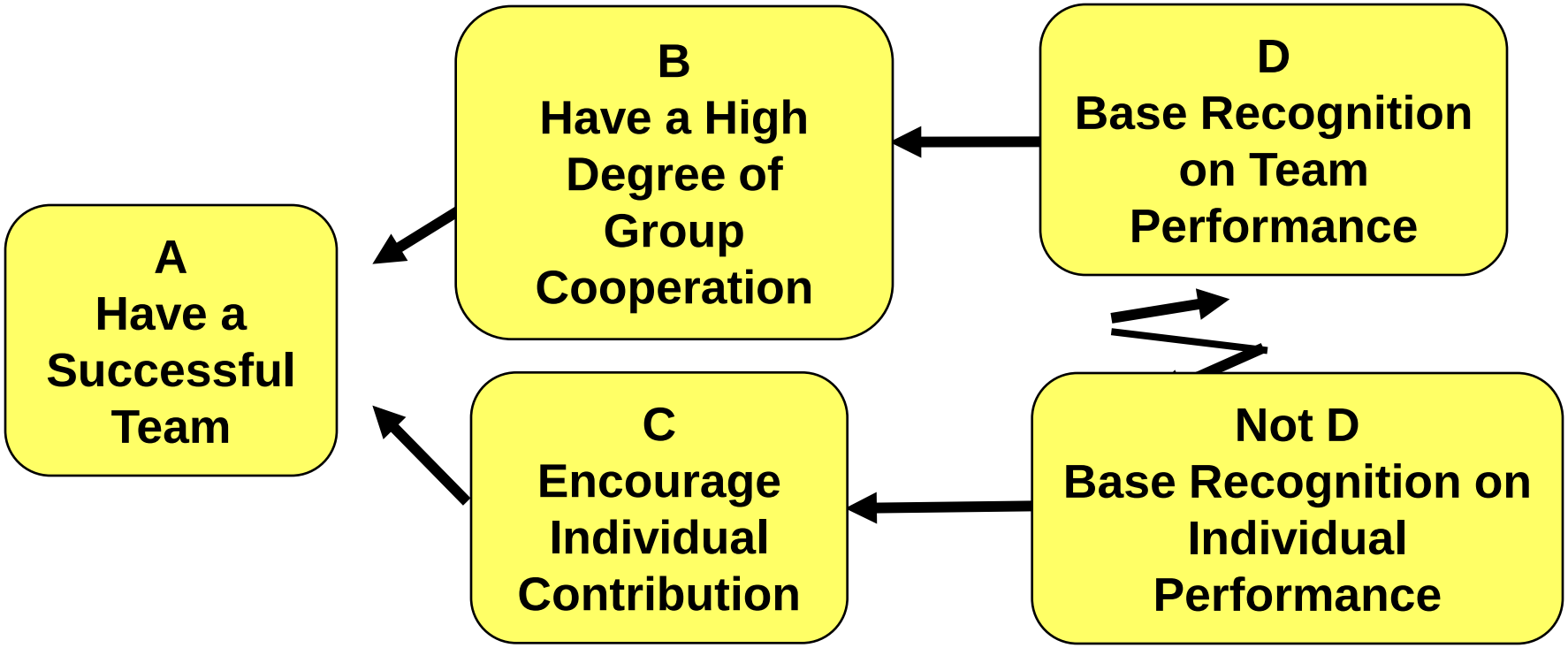
source: Washington State University-2010

Converting the Evaporating Cloud to Current Reality Tree

- **The next few steps are Dramatic Ones:**
  - Stand the Cloud on its point.
  - Turn around the arrows
  - Adjust the wording to make smooth "If … Then …" logic
  - Add the Assumptions with the 'And' Connectors
- **The result is <u>the start</u> to the Current Reality Tree!**

source: Washington State University-2010

Start with the Conflict Cloud



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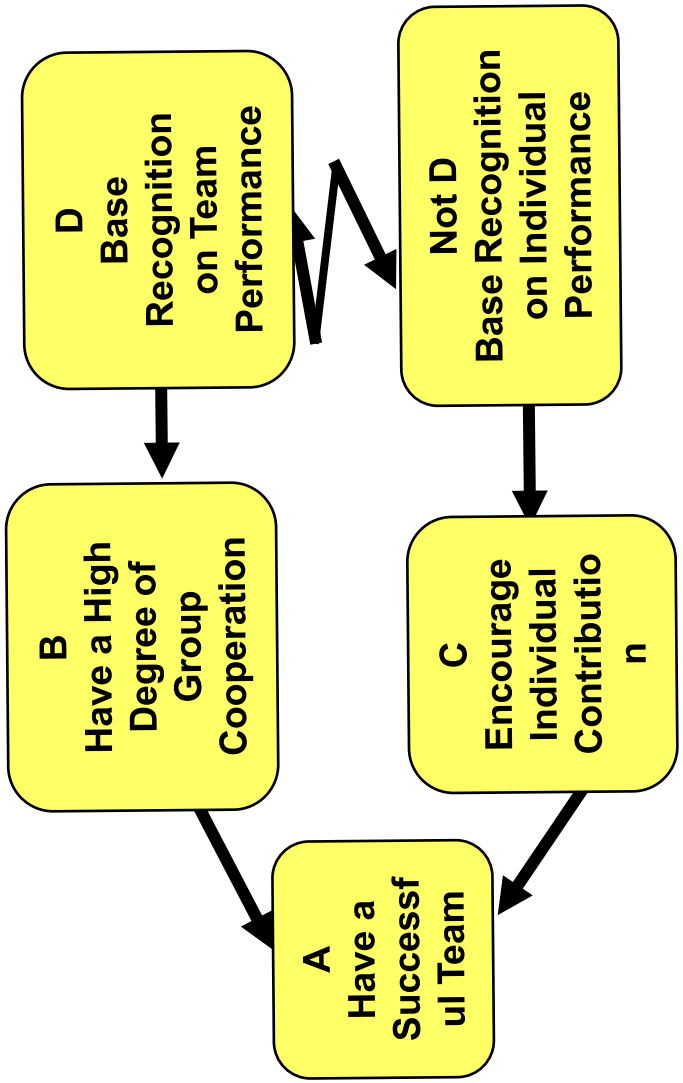
Flip in on it's end



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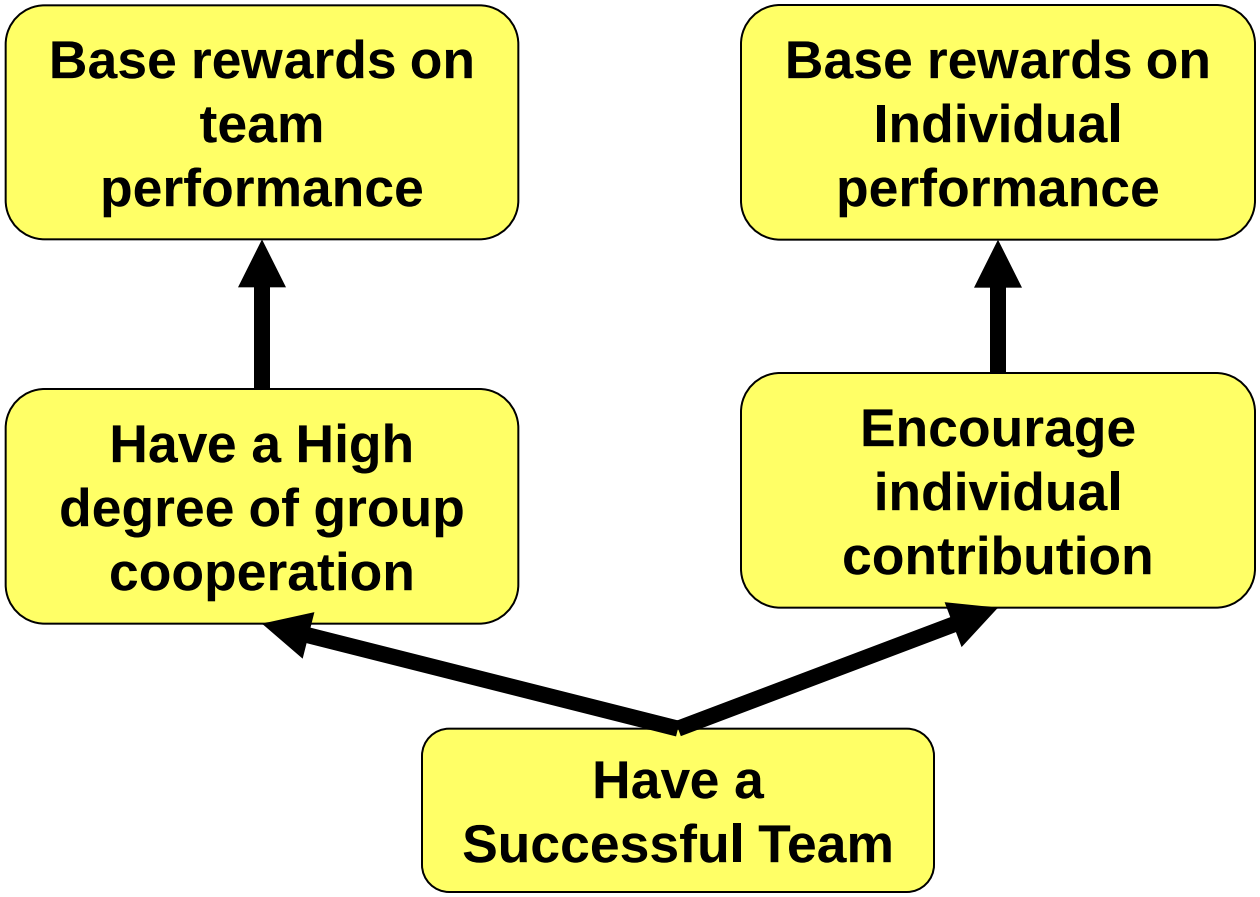
Turn the Arrows Around



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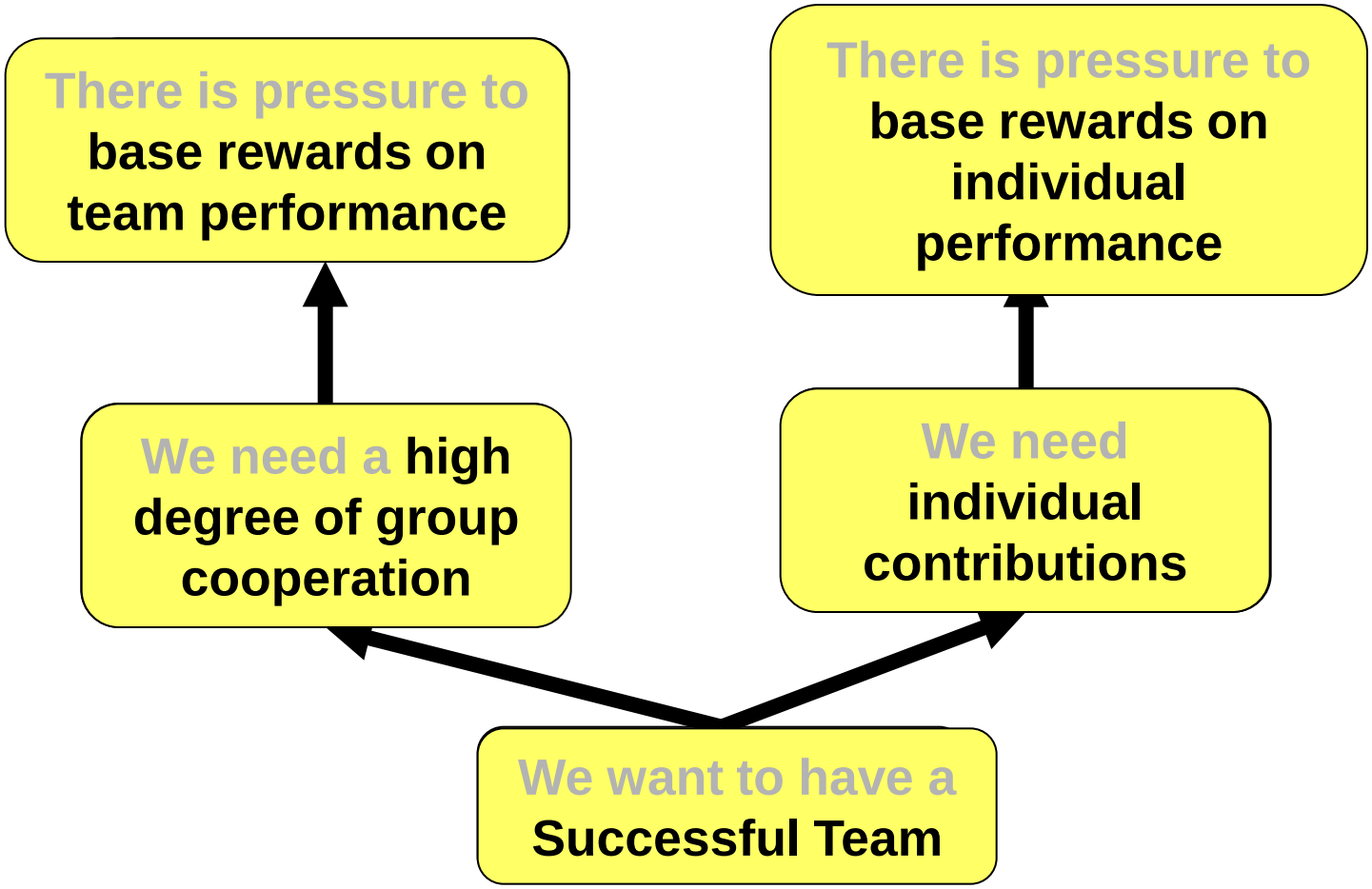
Adjust the working to “If ... Then …” Logic (note the key words added to make this easier – include them)



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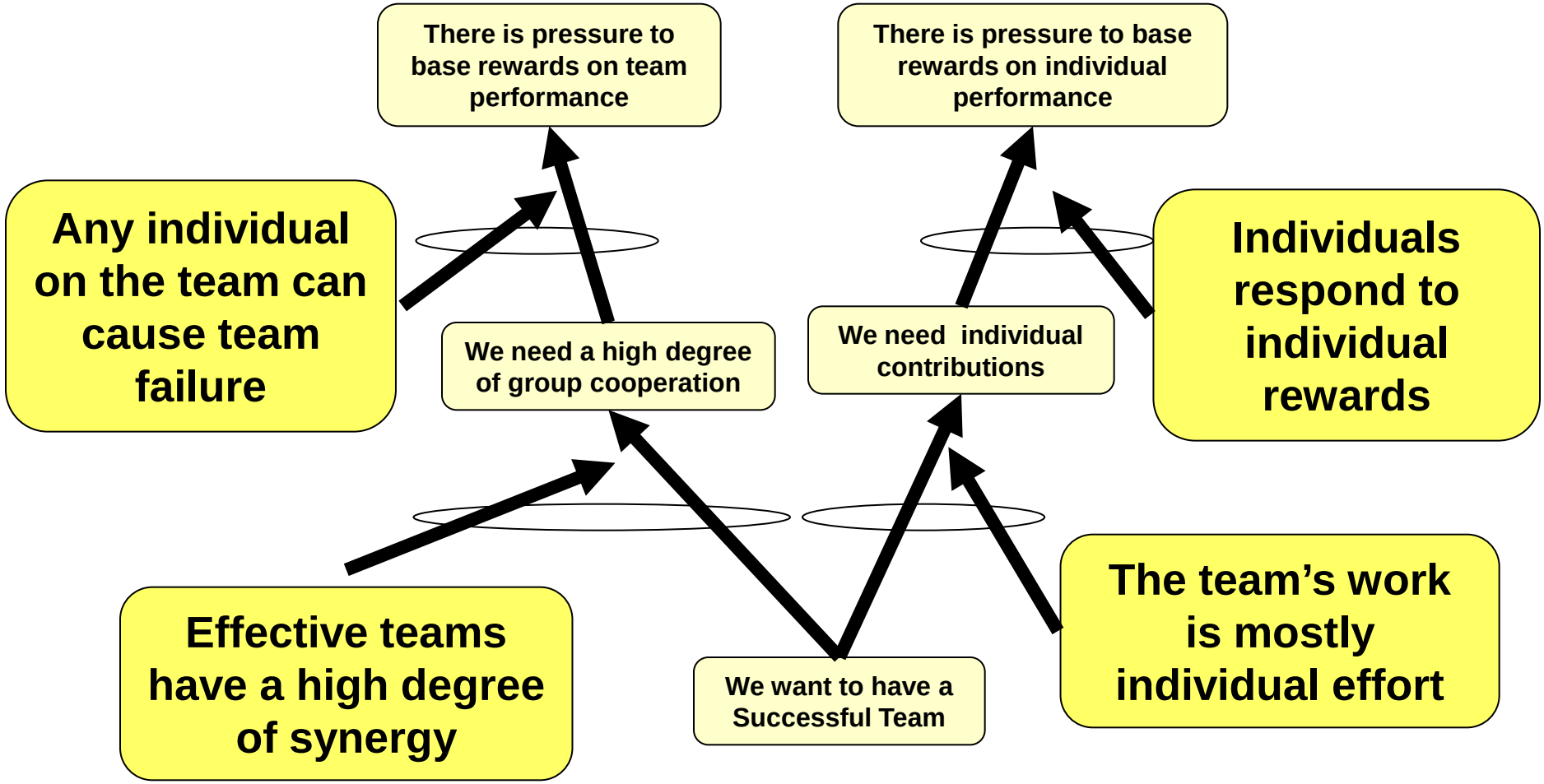
Add in at least one Assumption for each arrow



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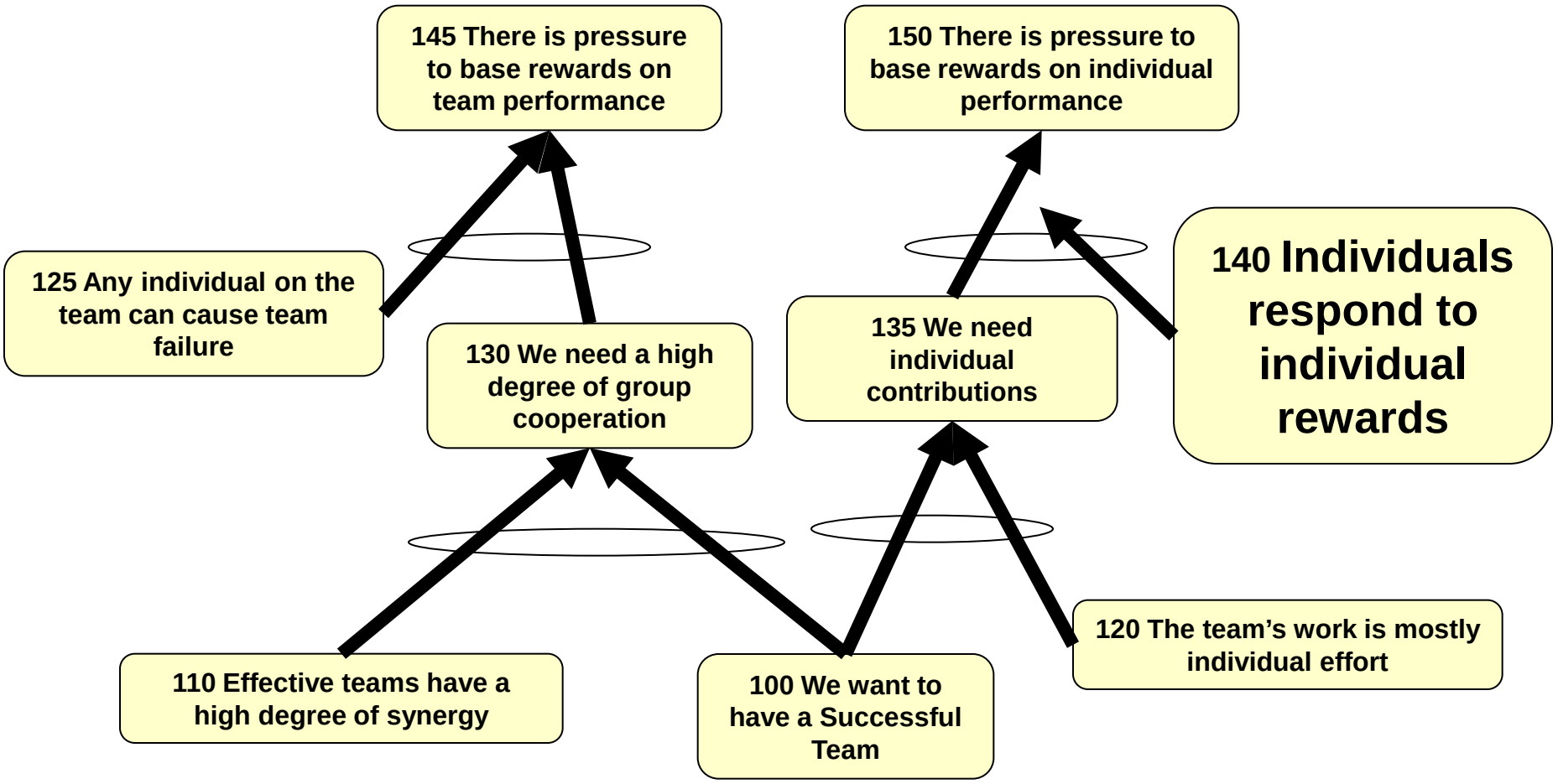
Check the Logic using the Categories of Legitimate Reservation

Numbers added as labels to entities to facilitate discussion



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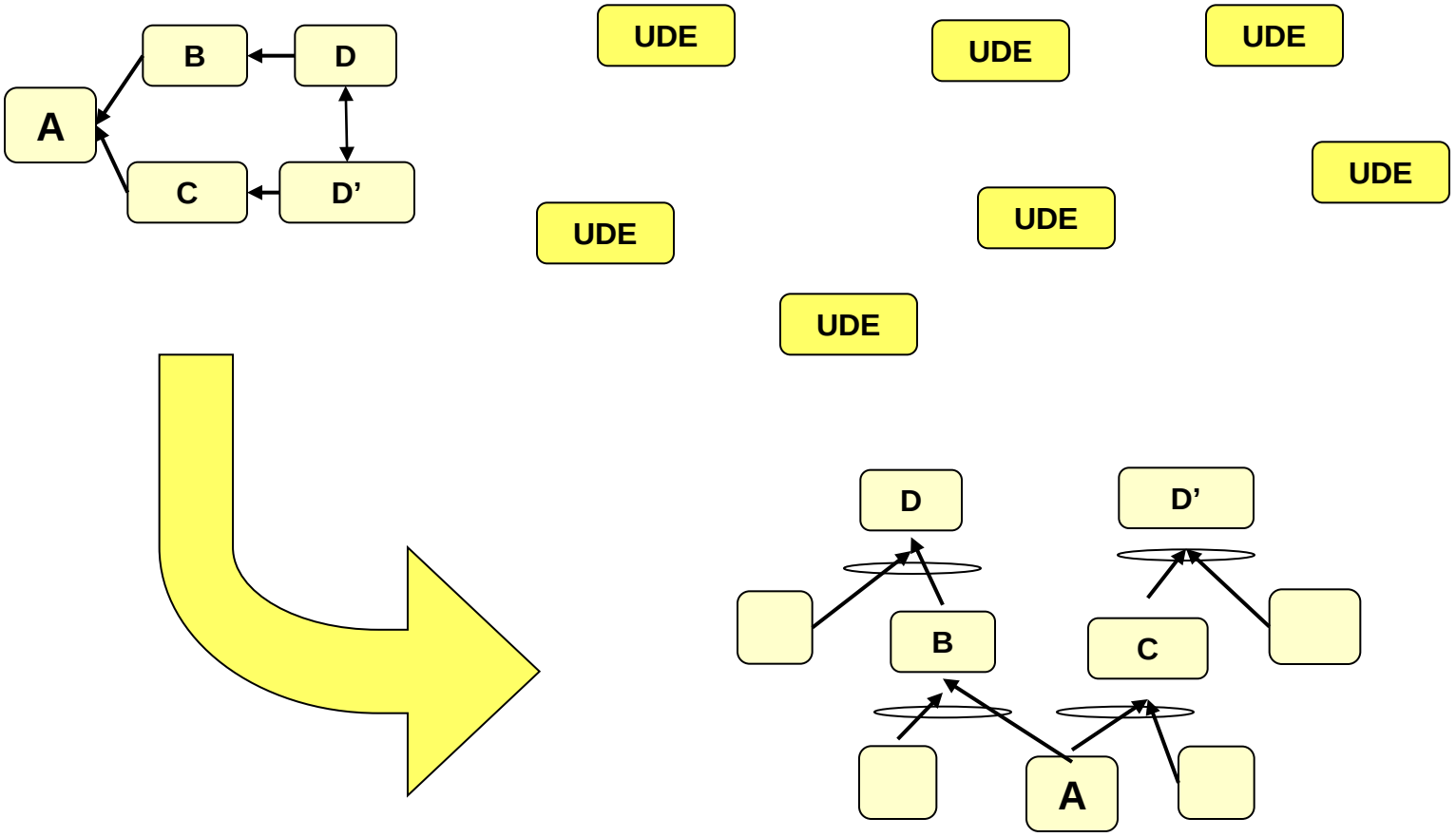
Connect the Core Conflict to the UDES for the CRT foundation



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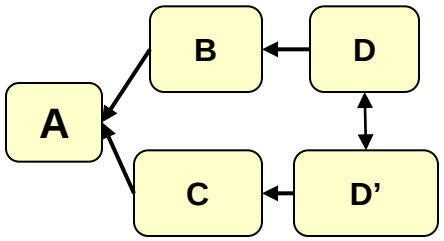
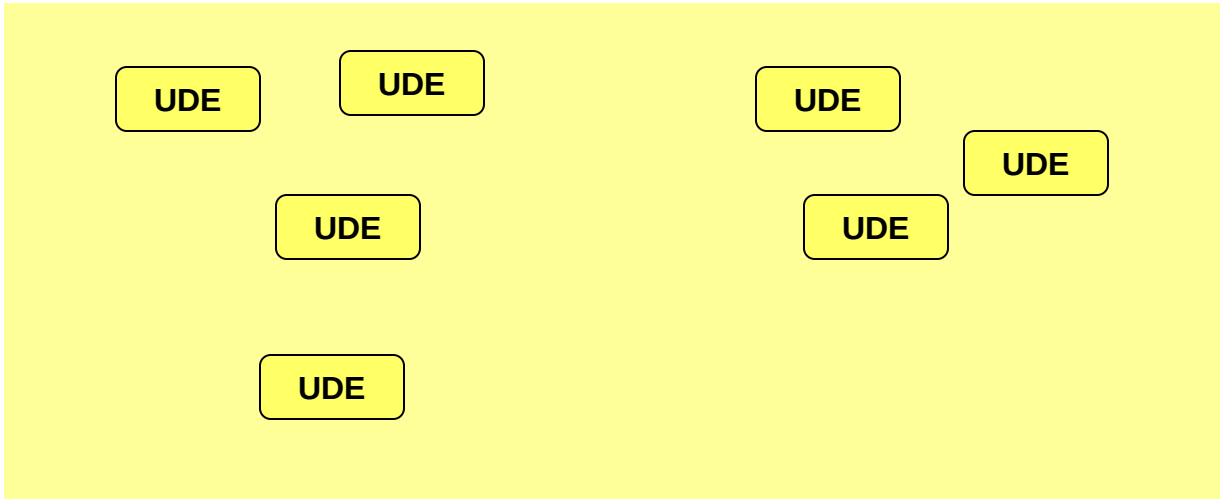
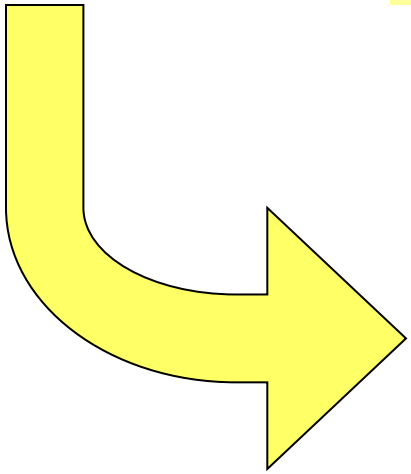
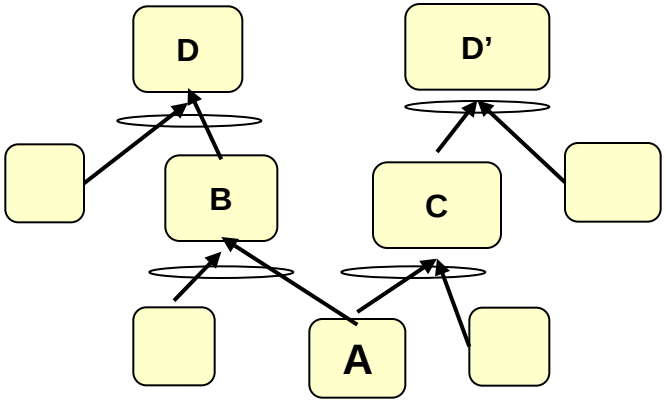
Starting Groups and Connections







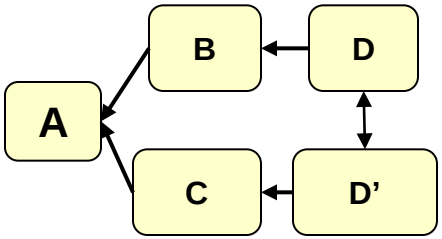


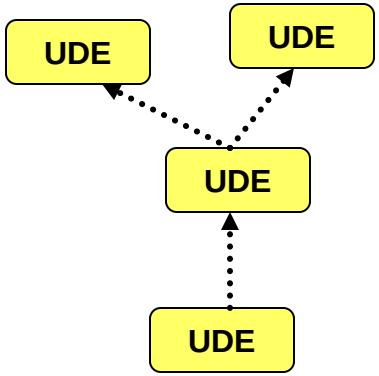
Do some UDEs seem related?
One follow the other?

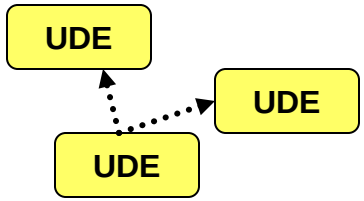
Group them!

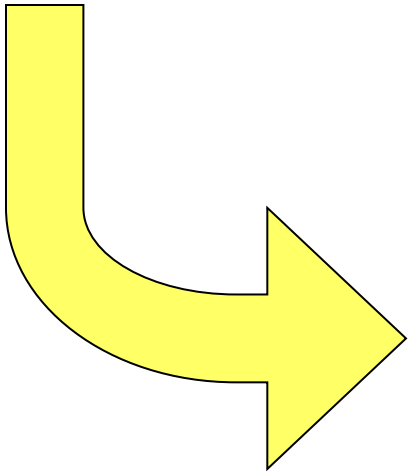
source: Washington State University-2010

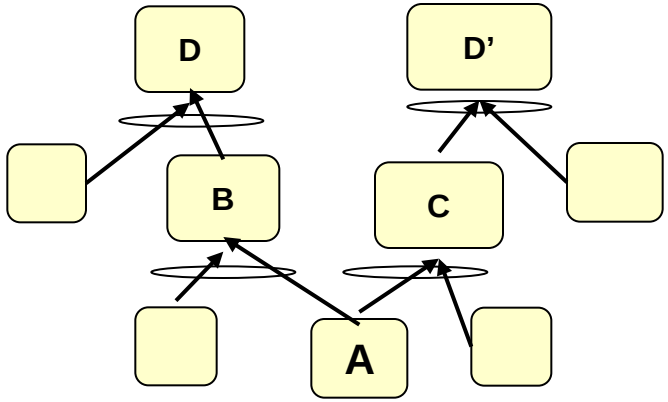
Simple, Temporary Connections





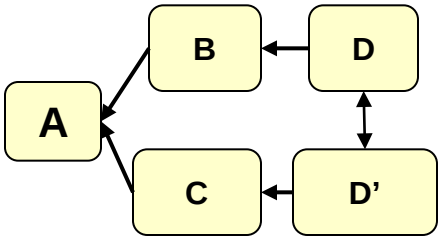


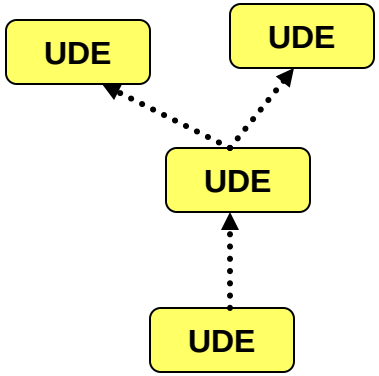


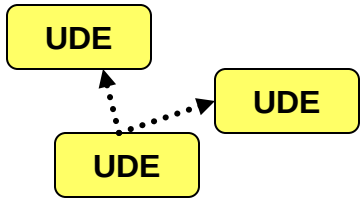


source: Washington State University-2010

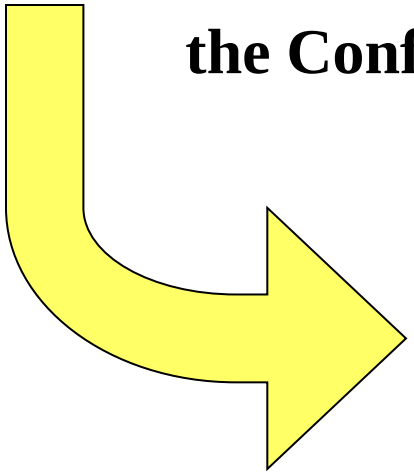
Look for the Result of the Conflict

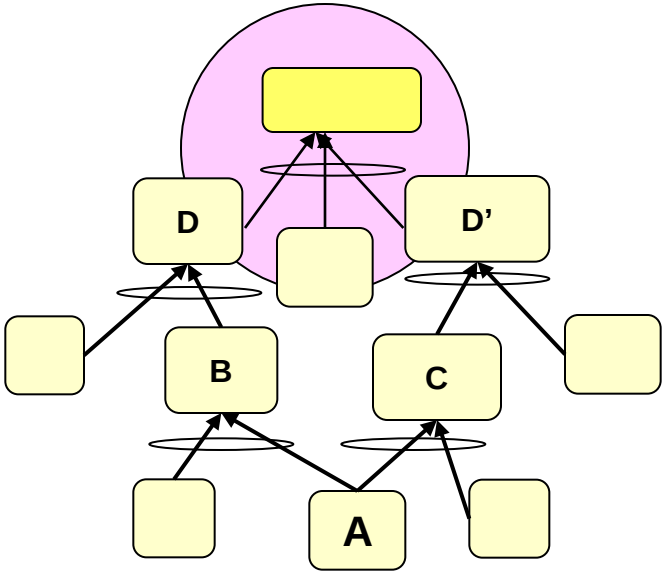






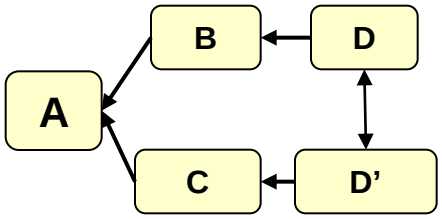
Evidence of the Conflict

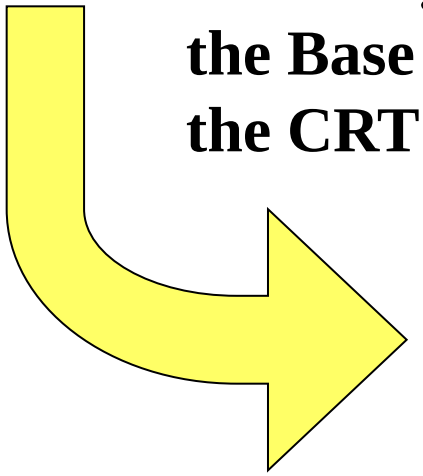




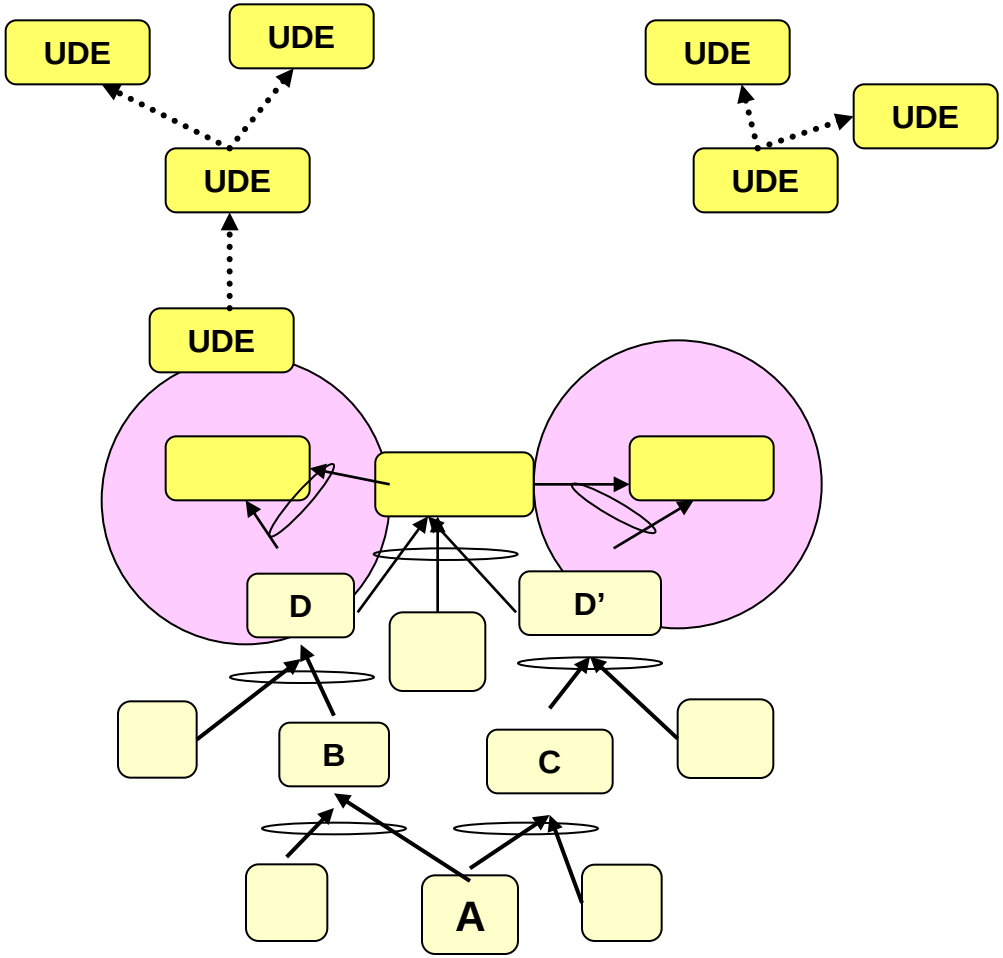
source: Washington State University-2010

What Happens because of the Conflict and D/D'?



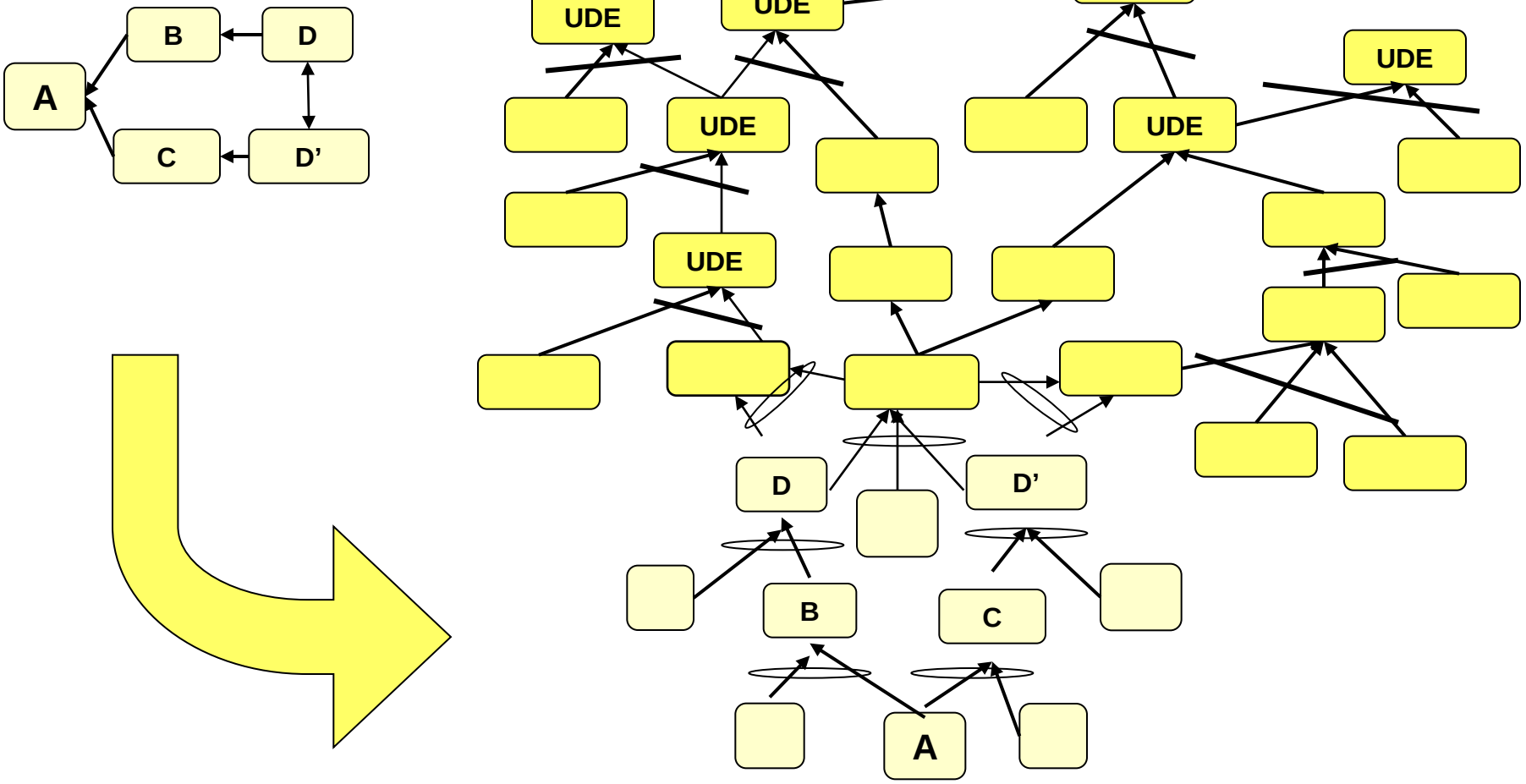


Widening the Base of the CRT



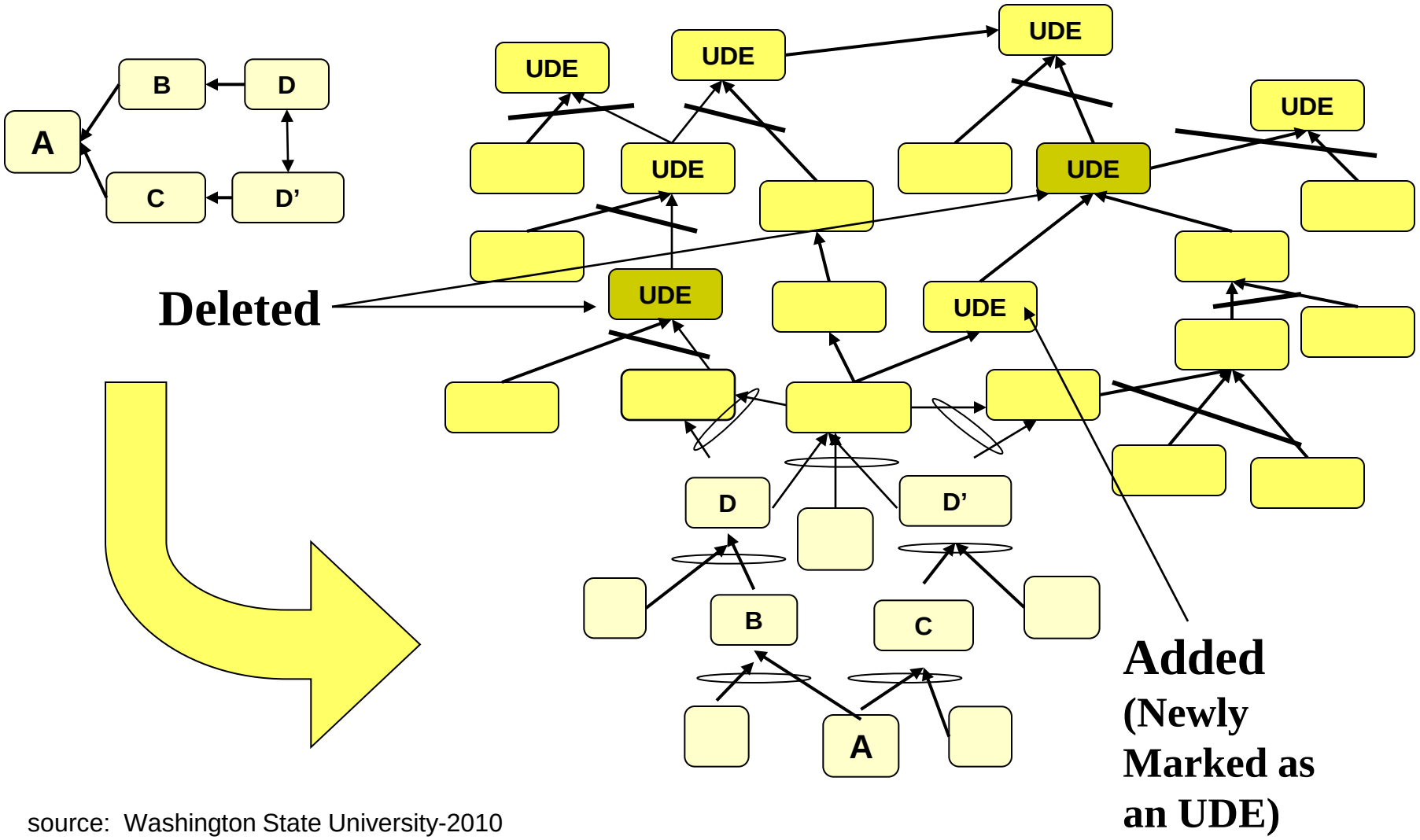
source: Washington State University-2010

Scrutinize the Entire Tree Using the CLR



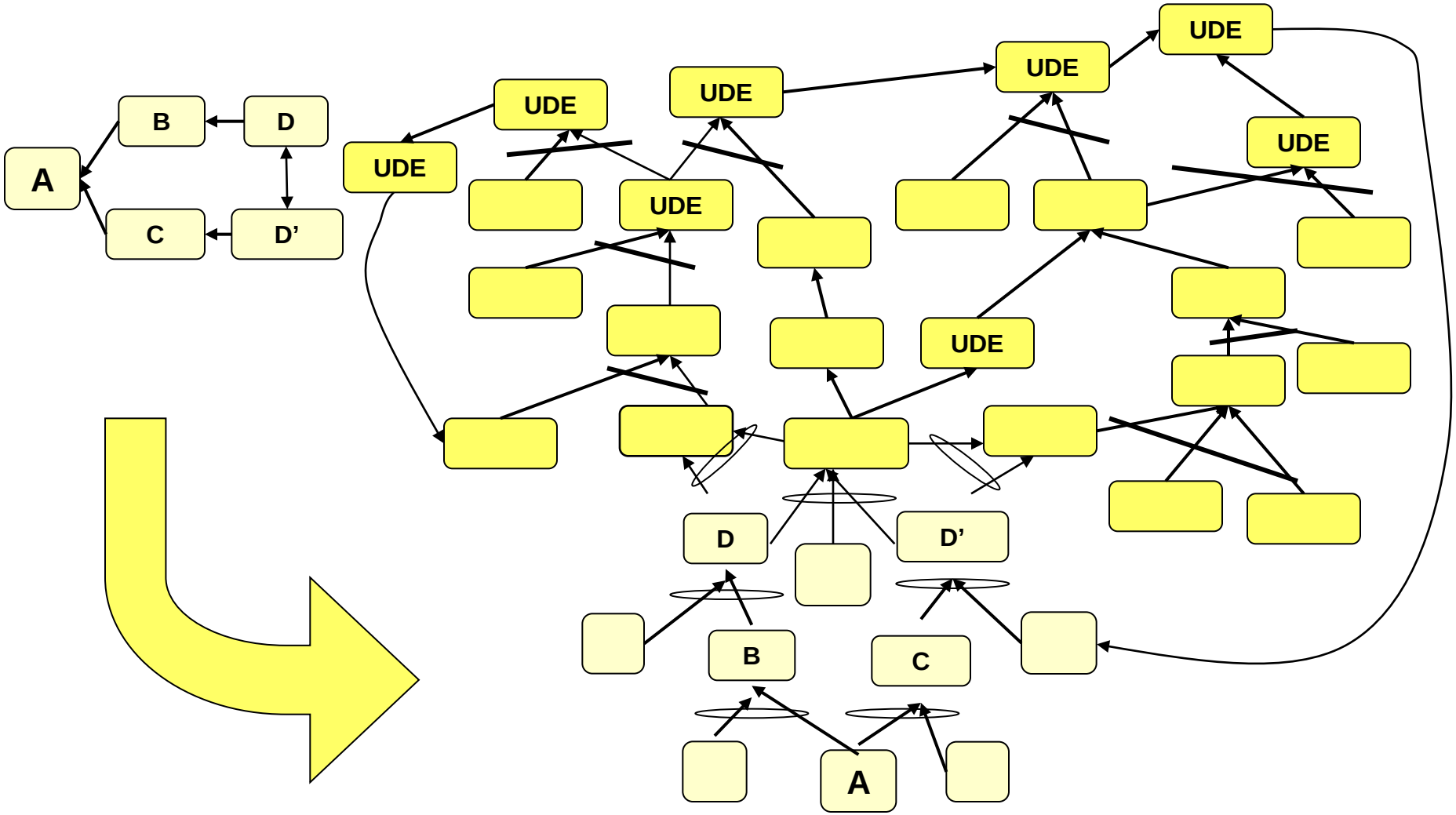
source: Washington State University-2010

Re-Evaluate the UDES-Find New Ones/Delete Old Ones



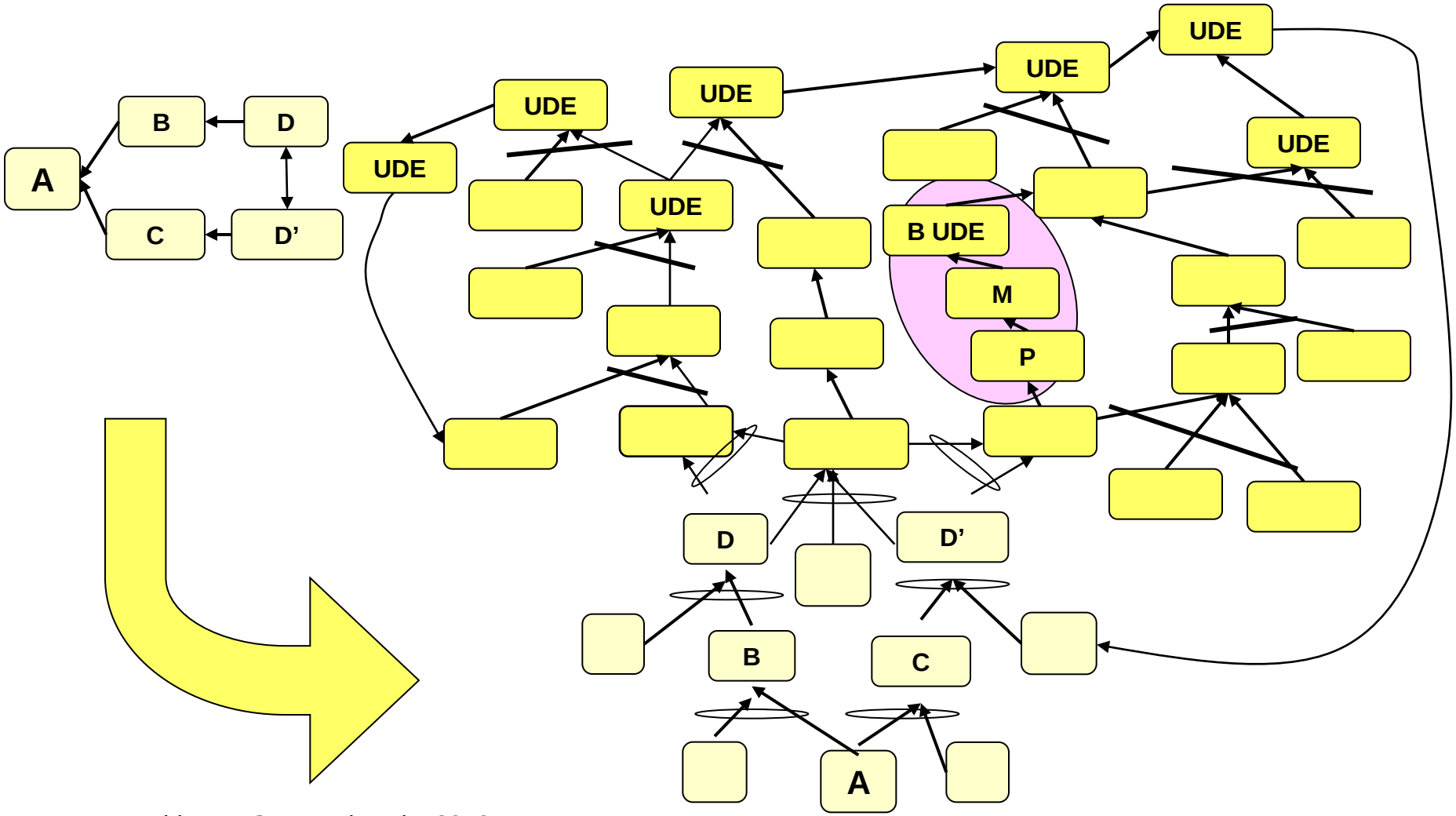
source: Washington State University-2010

Look for Feedback Loops



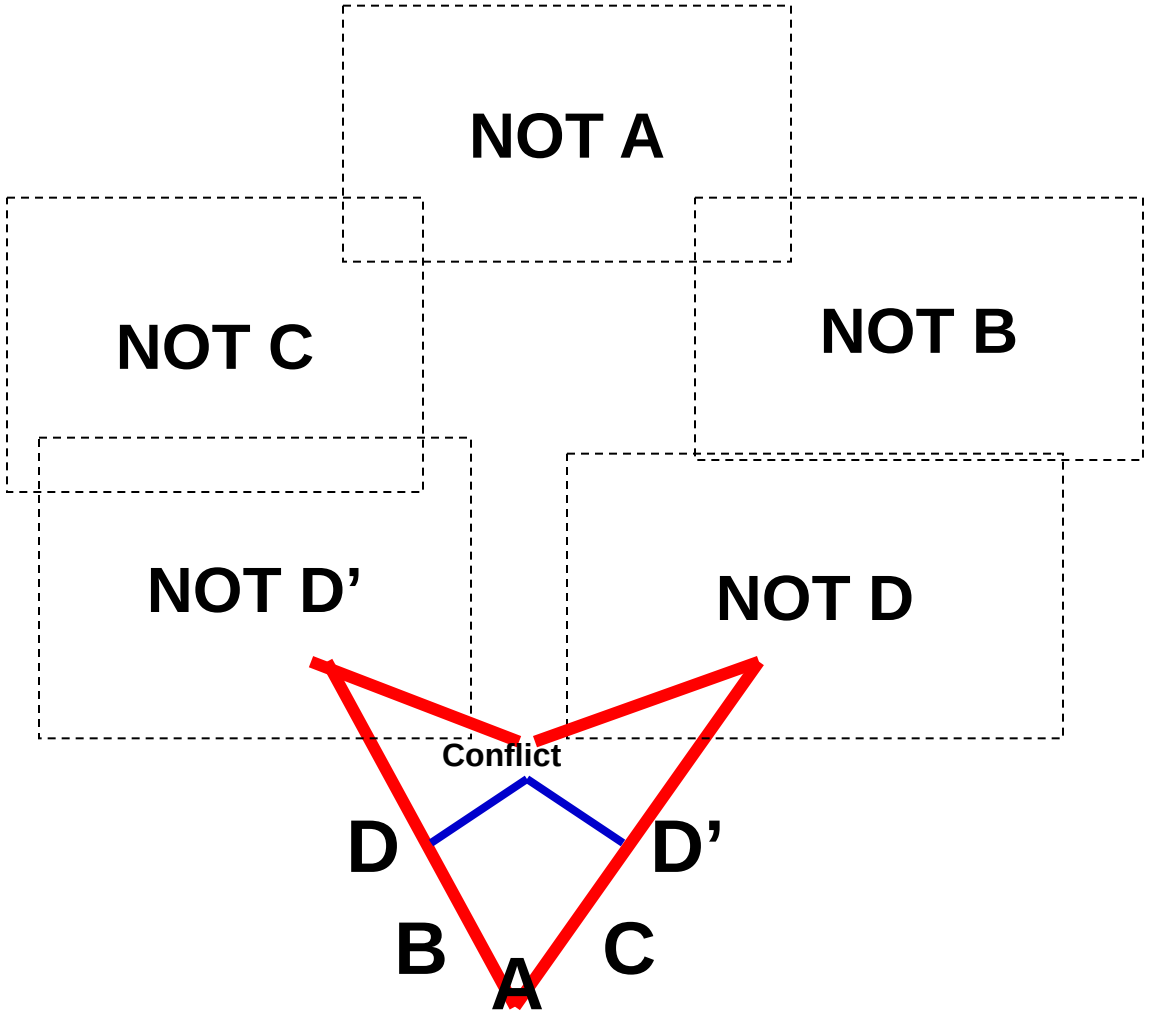
source: Washington State University-2010

Look for Policy, Measurement, Behavior Issues (add them if they are not there)



source: Washington State University-2010

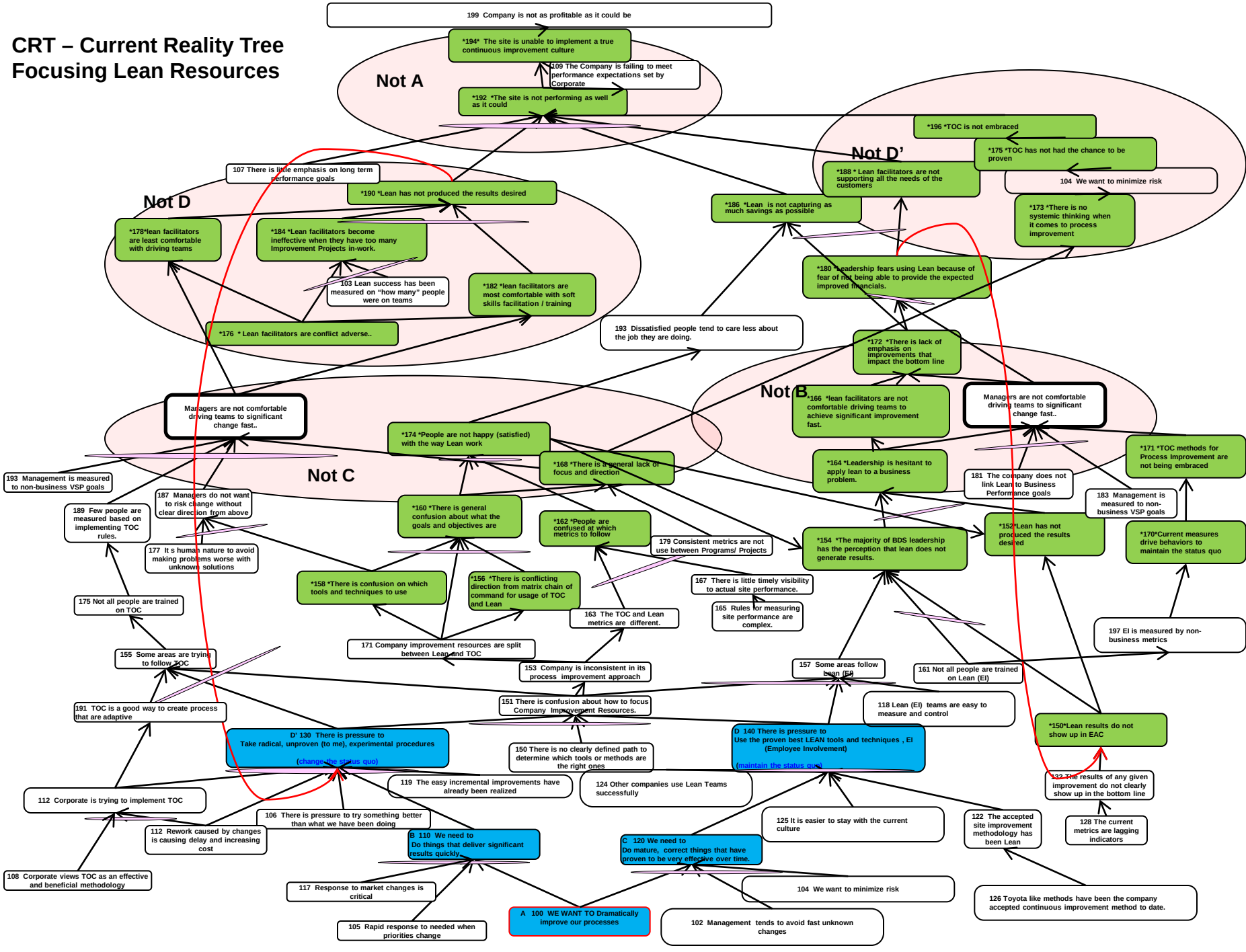
The Cone Shape Then Becomes...



- The addition to the Base divides the CRT quickly
- Builds upwards quickly
- The Regions help show what is missing
- Allows a Thinking Process person to view the CRT and Scrutinize Quickly

source: Washington State University-2010

CRT – Current Reality Tree
Focusing Lean Resources



Applying Theory of Constraints Tools to Focus Lean Development

- **Introduction to Theory of Constraints**
- **How to use the Thinking Process Tools**
  - **What to Change**
    - Evaporating Clouds to identify conflicts
    - Current Reality Tree
  - **What to Change to**
    - Strategic Future Reality Tree
  - **How to cause the Change**
    - Prerequisite Trees and Transition Trees
    - Strategy and Tactics Tree

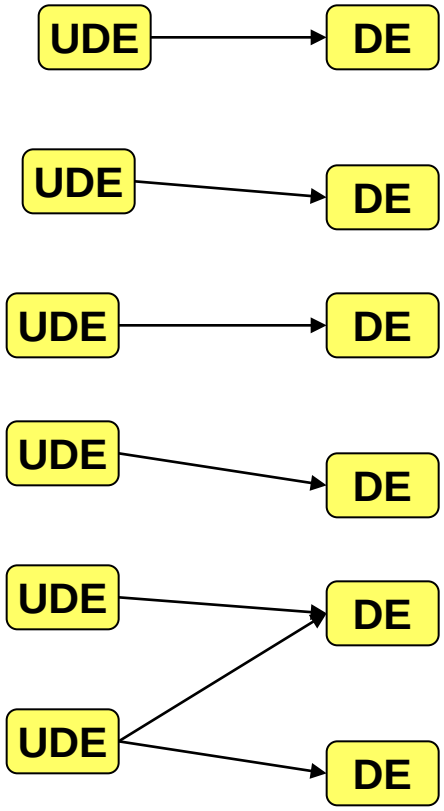
The Future Reality Tree

- **The FRT is NOT detailed. It's a HIGHer order of abstraction**
- **Its purpose is to affirm direction and build confidence**
- **Don't get caught up in too much minutia! Make it High Level & Logically Sufficient**
- **The PRT and TT will do the detail work later.**
- **The Core Conflict already raised your thinking to a higher level of abstraction from the UDES. Let the FRT stay near that level**
- **Still, you need enough detail to achieve the DEs**

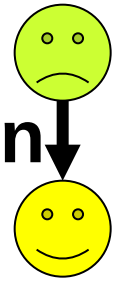
source: Washington State University-2010

Convert UDEs to DEs

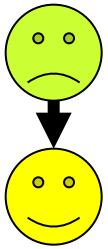
- **Convert the Undesirable Entities into a Positive Desirable Effect.**



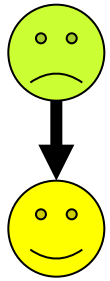
- **UDE: Behind the Scenes maneuvering (politics) is common**
- **DE: People are very cooperative**



- **UDE: People are frustrated**
- **DE: People are happy on the job**

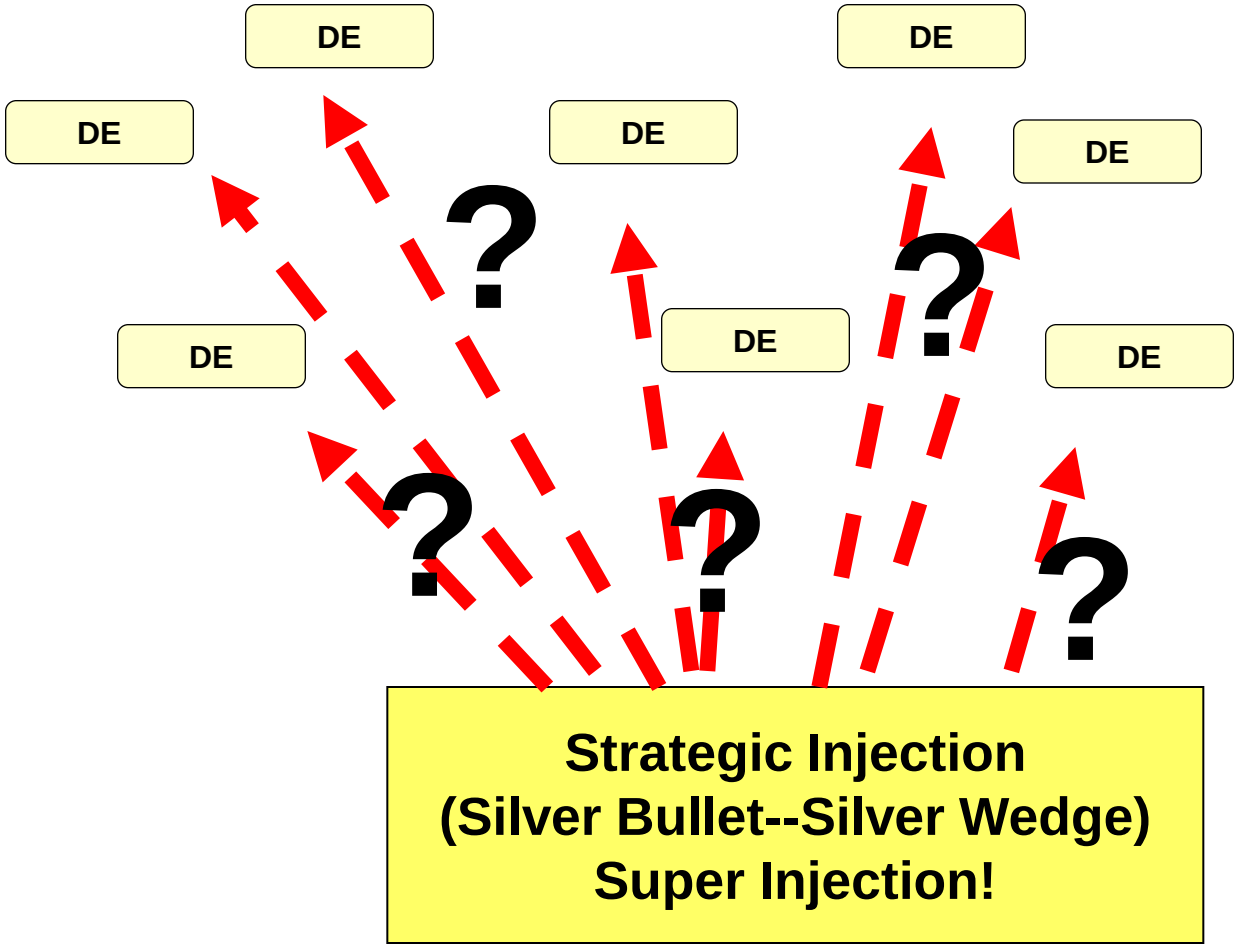


- **UDE: Many people are valued some what arbitrarily**
- **DE: People know their contribution will be appreciated**



source: Washington State University-2010

Reaching our Future



We want to create our Desired Effects (opposites of our UDEs)

Will the Silver Bullet get us there?

source: Washington State University-2010

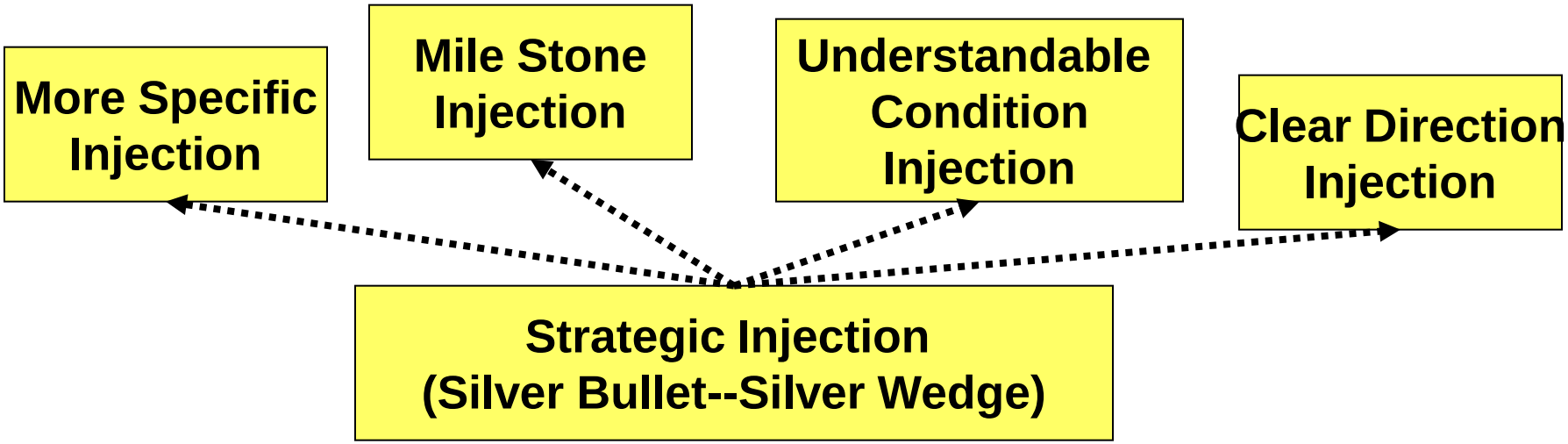
Finding Breakthroughs (the next step)

- **Breakthrough Solutions are Silver Bullets (or at least Silver Wedges, powerful wedges that only need a crack in the wall to allow us to "work our way through").**
- **How do we find them?**
  - By Observation
  - By Challenge
  - By Reference Environment
- **The best are often The Impossible Ones**
- **If you can't find one, Just do the Opposite of the Rest of the World.**

source: Washington State University-2010

Relationship of the Super Injection

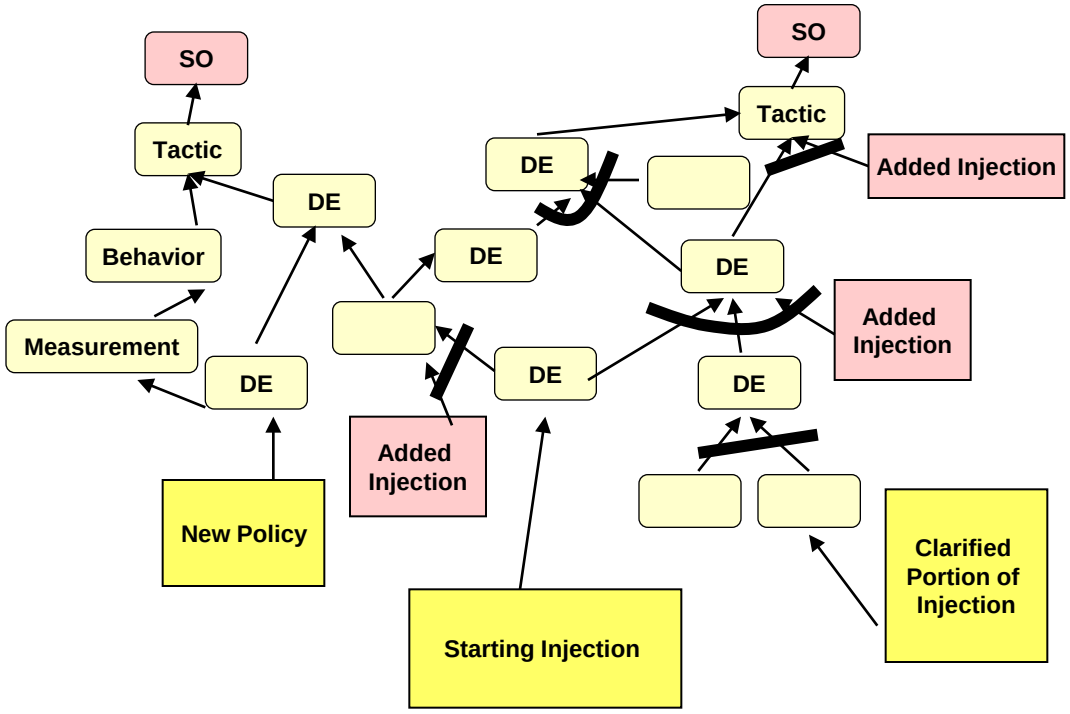
- **The Super Injection, may represent the strategic direction.**
- **In order to build a solid FRT, it may need to be broken into it's component parts. The definition of the component parts then assist in the development of the FRT.**



source: Washington State University-2010

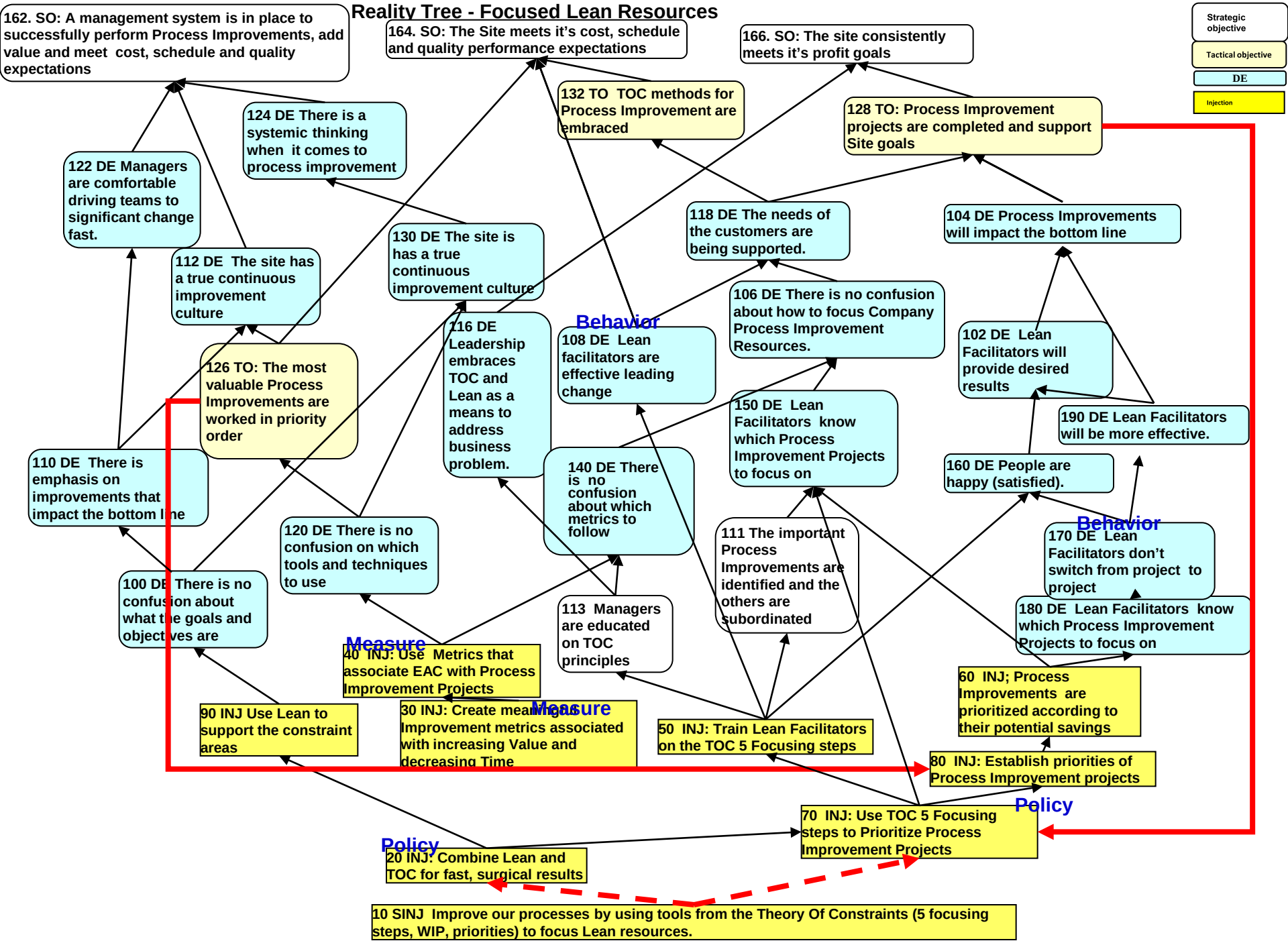
The Resulting Future Reality Tree

The FRT gives the road map that confirms we are on the right track.
It shows our injection(s) can succeed.
It gives confidence and direction in moving into the future.



source: Washington State University-2010

Reality Tree - Focused Lean Resources



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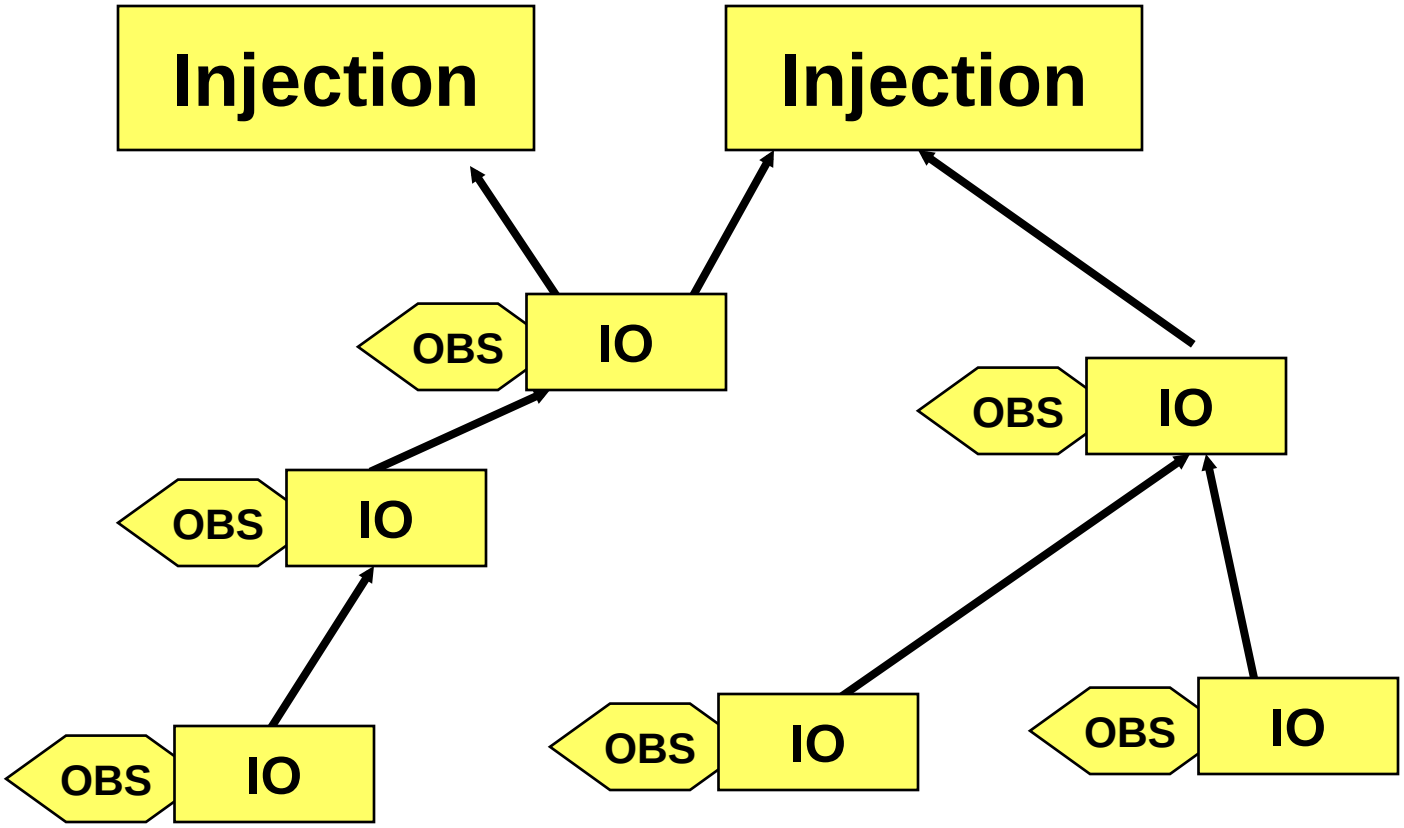
The Prerequisite Tree

The purpose of the Prerequisite Tree is to surface potential obstacles (OBS) to be overcome



Use TOC 5 Focusing steps to Prioritize Process Improvement Projects

Obstacle	Tactical (Intermediate) Objective
Lean Facilitators and Management don't know about the benefits of TOC	Train Lean Resources on TOC
Process with constraints are not identified or managed	identified and managed the priority Process Improvement projects
Key Lean Facilitators are overloaded	Support the Lean Facilitators working the priority Process Improvement projects
The capacity of the Lean Facilitators working Process Improvement projects is unknown	Identify constraints in current Lean assignment processes. Then subordinate all other Process Improvement projects .

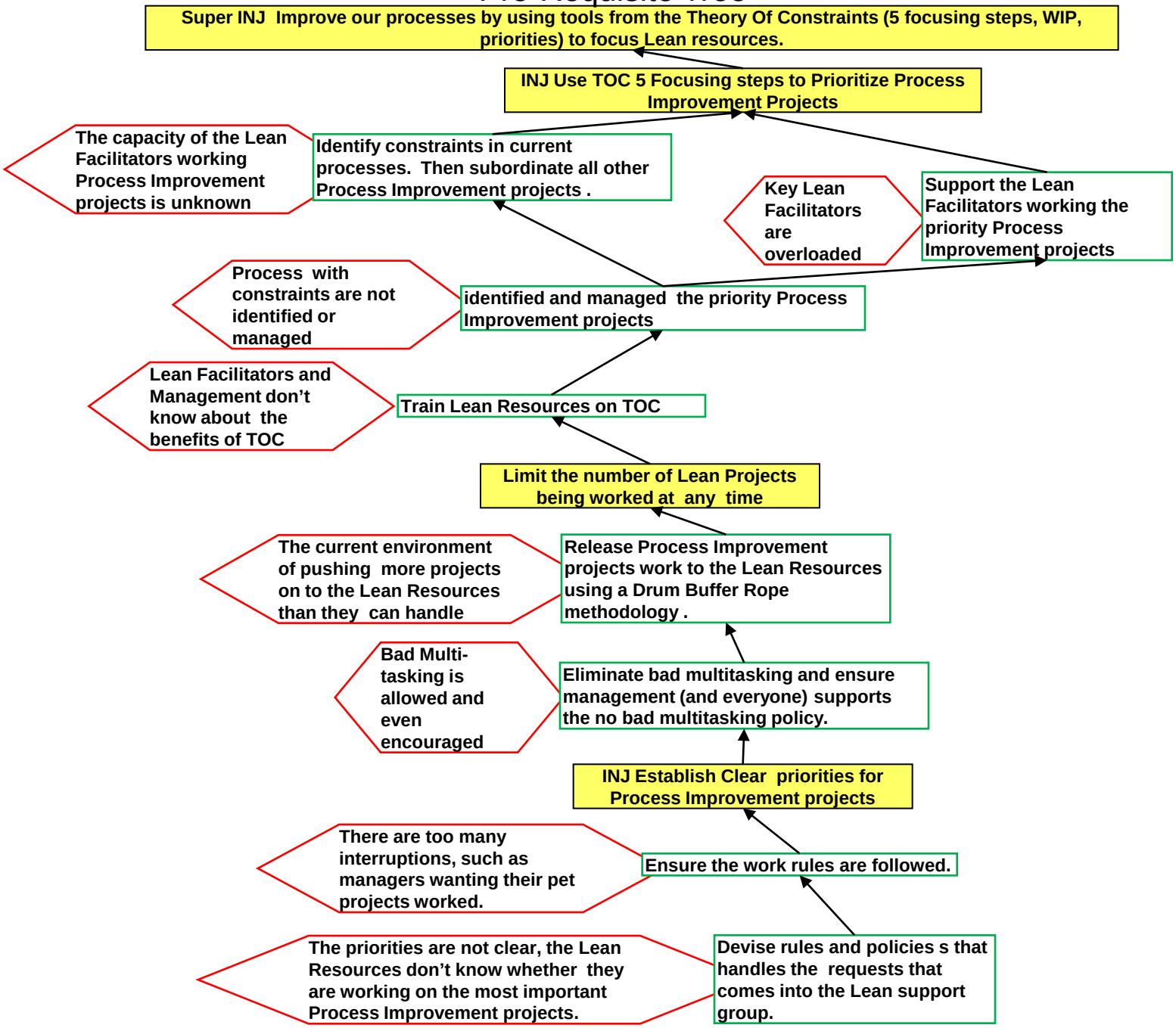
Limit the number of Lean Projects being worked at any time

Obstacle	Tactical (Intermediate) Objective
Bad Multi-tasking of Process Improvement Projects is allowed and even encouraged	Eliminate bad multitasking and ensure management (and everyone) supports the no bad multitasking policy.
The current environment of pushing more projects on to the Lean Resources than they can handle	Release Process Improvement projects work to the Lean Resources using a Drum Buffer Rope methodology .

Establish Clear priorities for Process Improvement projects

Obstacle	Tactical (Intermediate) Objective
The priorities are not clear, the Lean Resources don't know whether they are working on the most important Process Improvement projects.	Devise rules and policies s that handles the requests that comes into the Lean support group.
There are too many interruptions, such as managers wanting their pet projects worked.	Ensure the work rules are followed.

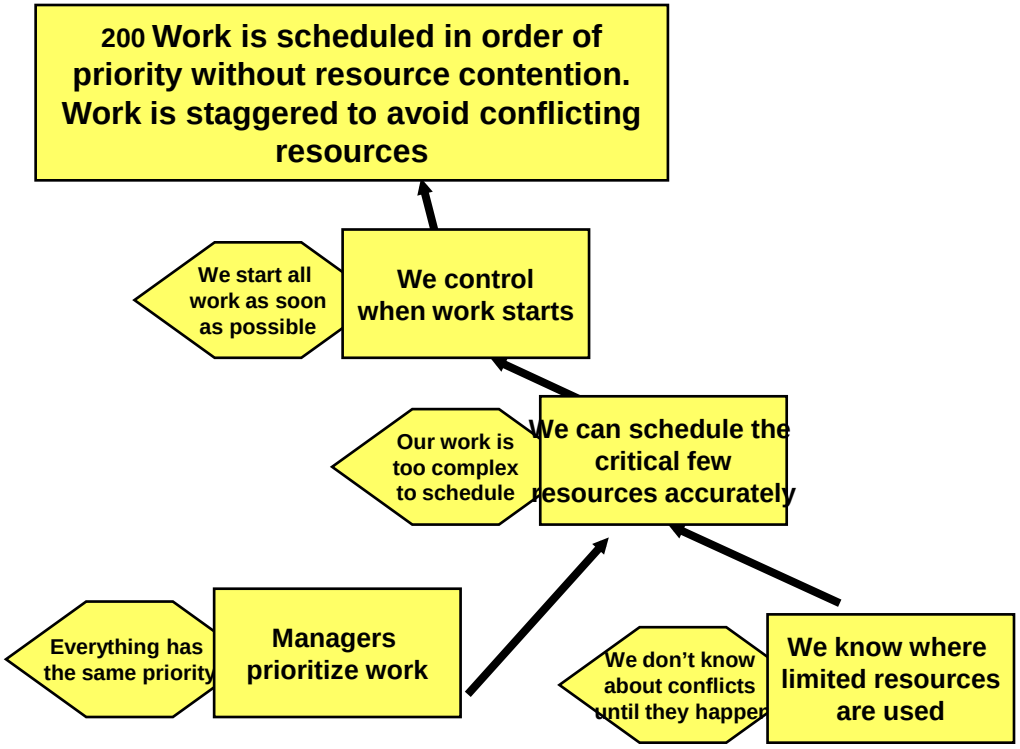
Pre-Requisite Tree



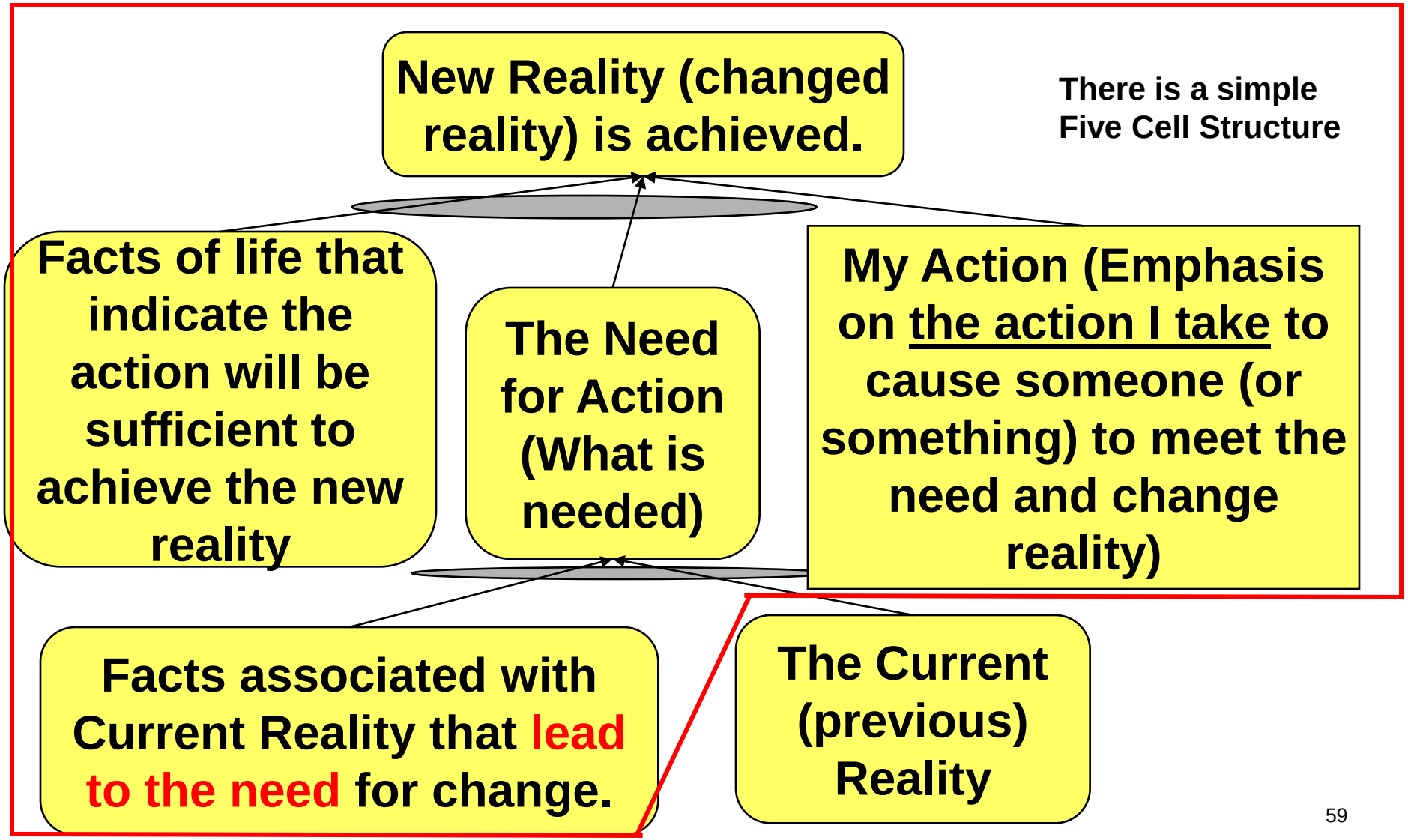
From the PRT to the Transition Tree

The Transition Tree CAUSES the Intermediate Objectives to exist so that the Injection will be achieved.

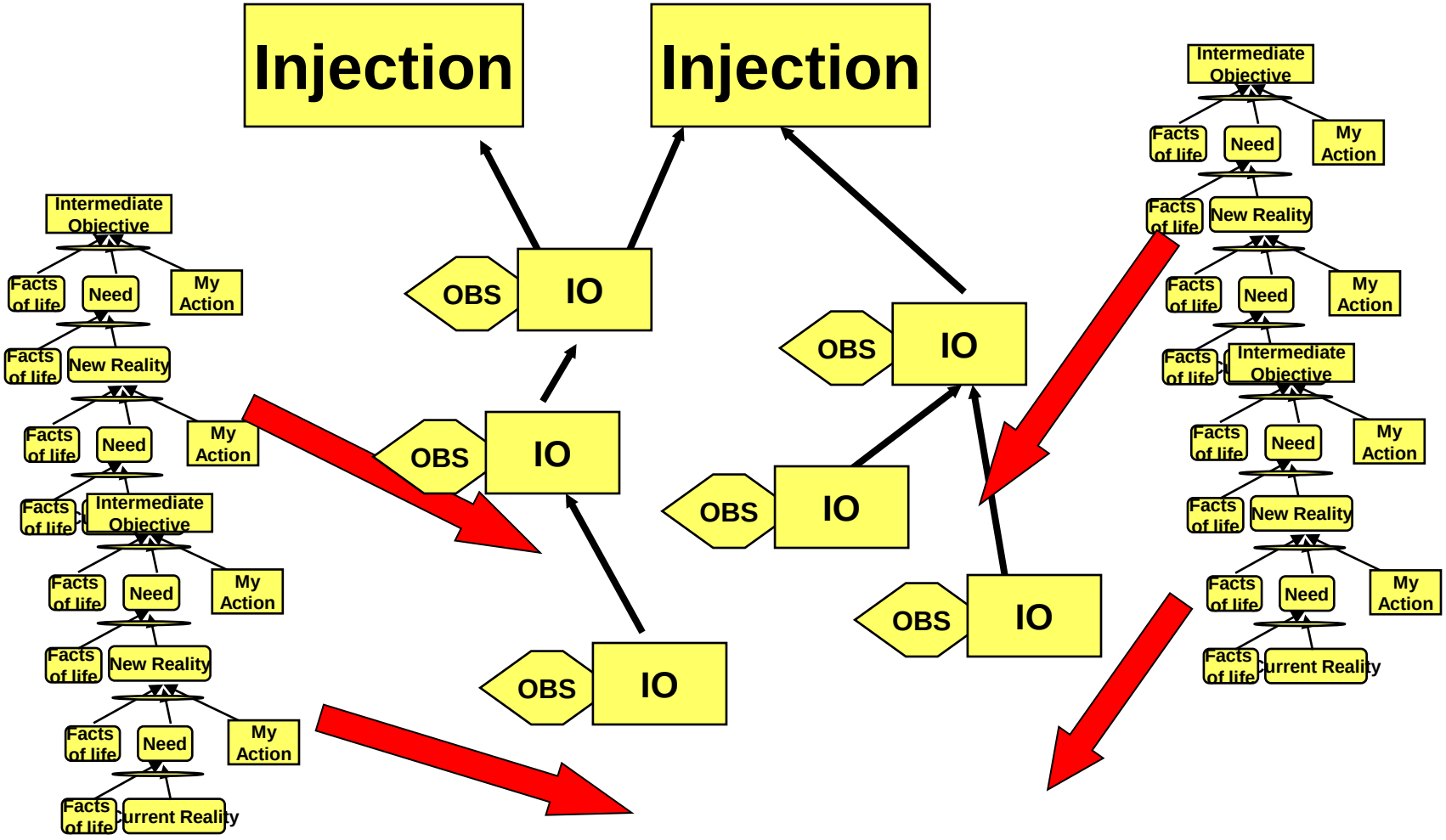
When all Tactical Objectives exist, the FRT becomes our new Current Reality!!!!

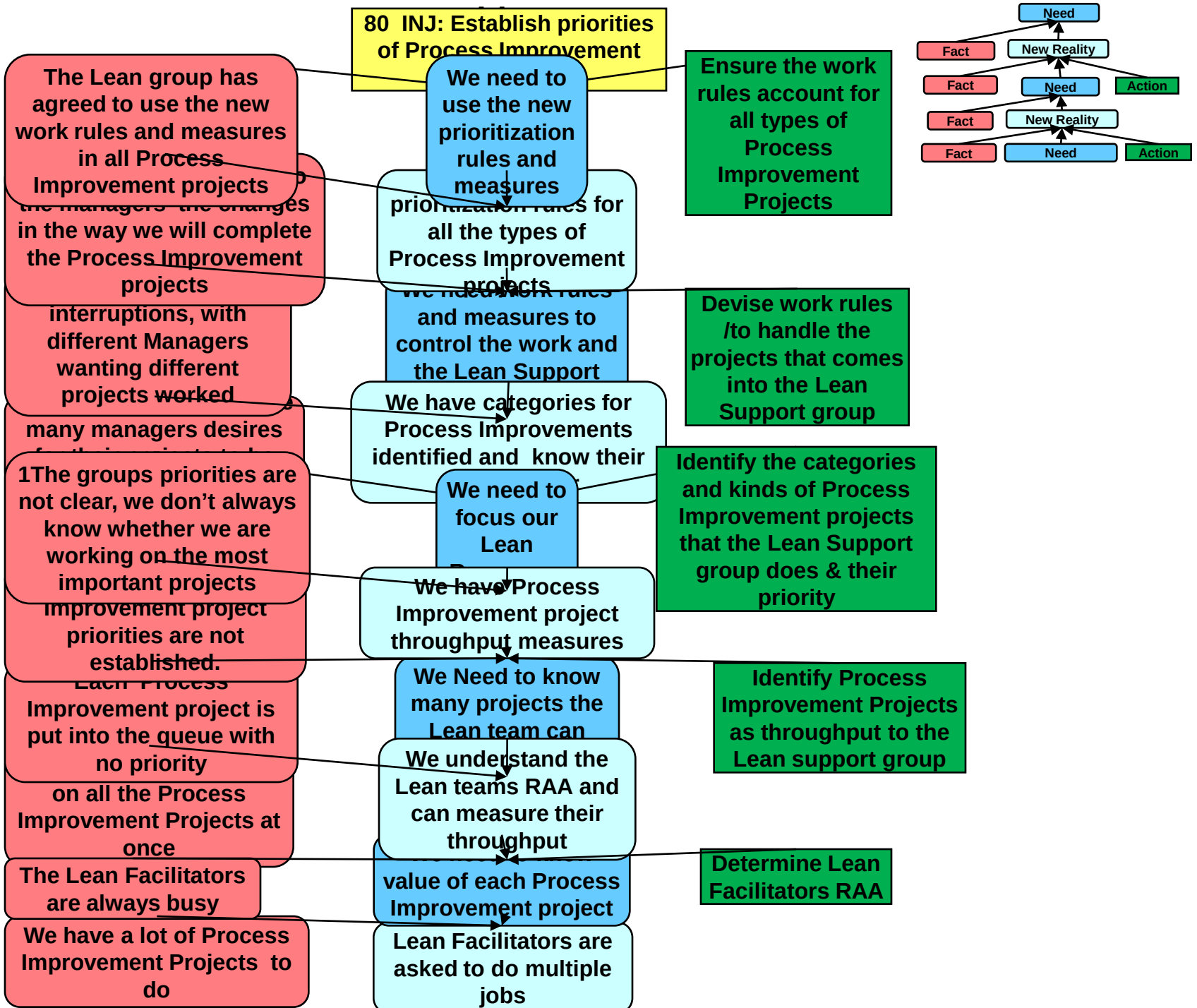


The Transition Tree (TT) follows a simple format to achieve: The Actions that Cause the Change

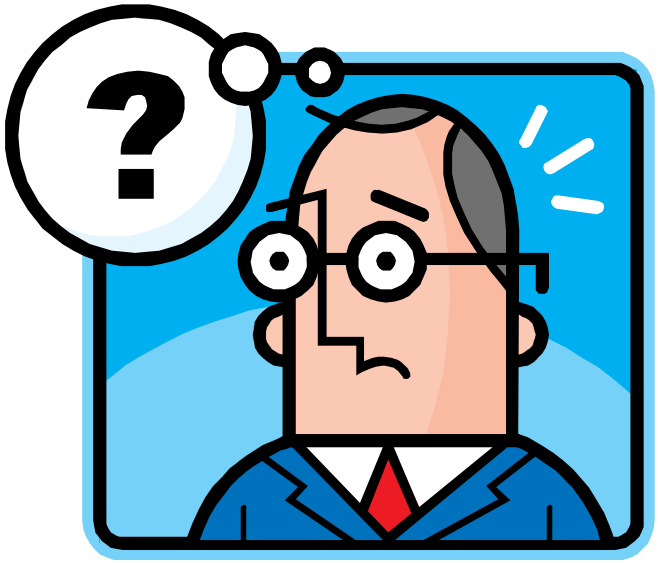


The Transition Tree Fills Logic Below and Within the Gap between the Intermediate Objectives of the PRT




80 INJ: Establish priorities of Process Improvement
Need
Fact
New Reality
Fact
Need
Action
Fact
New Reality
Fact
Need
Action
The Lean group has agreed to use the new work rules and measures in all Process Improvement projects
We need to use the new prioritization rules and measures
Ensure the work rules account for all types of Process Improvement Projects
in the way we will complete the Process Improvement projects
prioritization rules for all the types of Process Improvement projects
interruptions, with different Managers wanting different projects worked
and measures to control the work and the Lean Support
Devise work rules /to handle the projects that comes into the Lean Support group
We have categories for Process Improvements identified and know their
1The groups priorities are not clear, we don't always know whether we are working on the most important projects
We need to focus our Lean
Identify the categories and kinds of Process Improvement projects that the Lean Support group does & their priority
We have Process Improvement project throughput measures
Improvement project priorities are not established.
Improvement project is put into the queue with no priority
We Need to know many projects the Lean team can
Identify Process Improvement Projects as throughput to the Lean support group
We understand the Lean teams RAA and can measure their throughput
on all the Process Improvement Projects at once
The Lean Facilitators are always busy
value of each Process Improvement project
Determine Lean Facilitators RAA
We have a lot of Process Improvement Projects to do
Lean Facilitators are asked to do multiple jobs

Questions



Focusing Lean Support Group
Core Conflict Cloud

Story line: The company has limited resources to perform "Process Improvement" and support internal customer needs for Change and Improvement. These "change agents" are tasked with working with Employee Involvement Teams to create a culture of process improvement. There is an effort underway to explore TOC as an improvement tool.

Boeing Defense, Space & Security | Wichita Engineering

Combine LEAN and TOC for fast, surgical results!

Train TOC folks on how they can benefit from LEAN (to improve the difficult processes they find – in CCPM for sure – and other bottleneck areas).

Assumptions
1. There is pressure to try something better than what we have been doing
2. Our customer has changing requirements
3. The customer wants products faster and cheaper
4. Difficult to schedule today what is going to occur more than 6 months in the future
5. Our project requirement are not all the same

Assumptions
1. Our current date driven scheduling causes us to have to do project rescheduling
2. There is pressure to try something better than what we have been doing
3. we need to improve our processes
4. TOC takes in to account delays and resources availability
5. TOC is a good way to create process that are adaptive

Dc.'
1. Take radical, unproven (to me), experimental procedures

Bc.
3 Do things that deliver significant results quickly

Use the Thinking Tools Process to establish priorities for Process Improvement Projects

Ac.
5 Dramatically improve our processes

Assumptions
1. We don't know where to focus resources
2. Implementing both concepts causes confusion
3. Lean and EI don't always deliver desired results
4. Not everyone knows TOC

Focus resources on where the highest savings are (largest improvement can be made – that contribute to Throughput immediately (or accelerate project management processes)

Cc.
4. Do mature, correct things that have proven to be very effective over time

Dc.
2. Use the best LEAN tools and techniques, EI (Employee Involvement)

Assumptions
1. We need to improve our processes
2. Stable processes makes jobs easier to manage
3. We know how to control stable process
4. If we change we might create an unstable process

Assumptions
1. Toyota like methods have been up to this point the company accepted method for continuous improvement.
2. Toyota is considered to be successful with their implementation of Lean Processes
3. The accepted site improvement methodology has been EI
4. It is easier to stay with the current culture
5. EI teams are easy to measure and control

Train Lean Facilitators on TOC

There is a method to create and maintain stable balanced processes (We become a fast, reliable source of expert knowledge and projects. We can pick and choose which, of many, contracts we will pursue. We are profitable. We can grow our capacity at a rate we choose.

Create meaningful improvement metrics associated with Increasing Value and decreasing Time

Find other ways to implement Employee Involvement (remove the obstacles to being fast and let the work itself be the reward)

In order to …
Objective

We need to …
Requirement

In order to…

We need to …
Prerequisite