Identify, Define, Bound & Explore Problem Space

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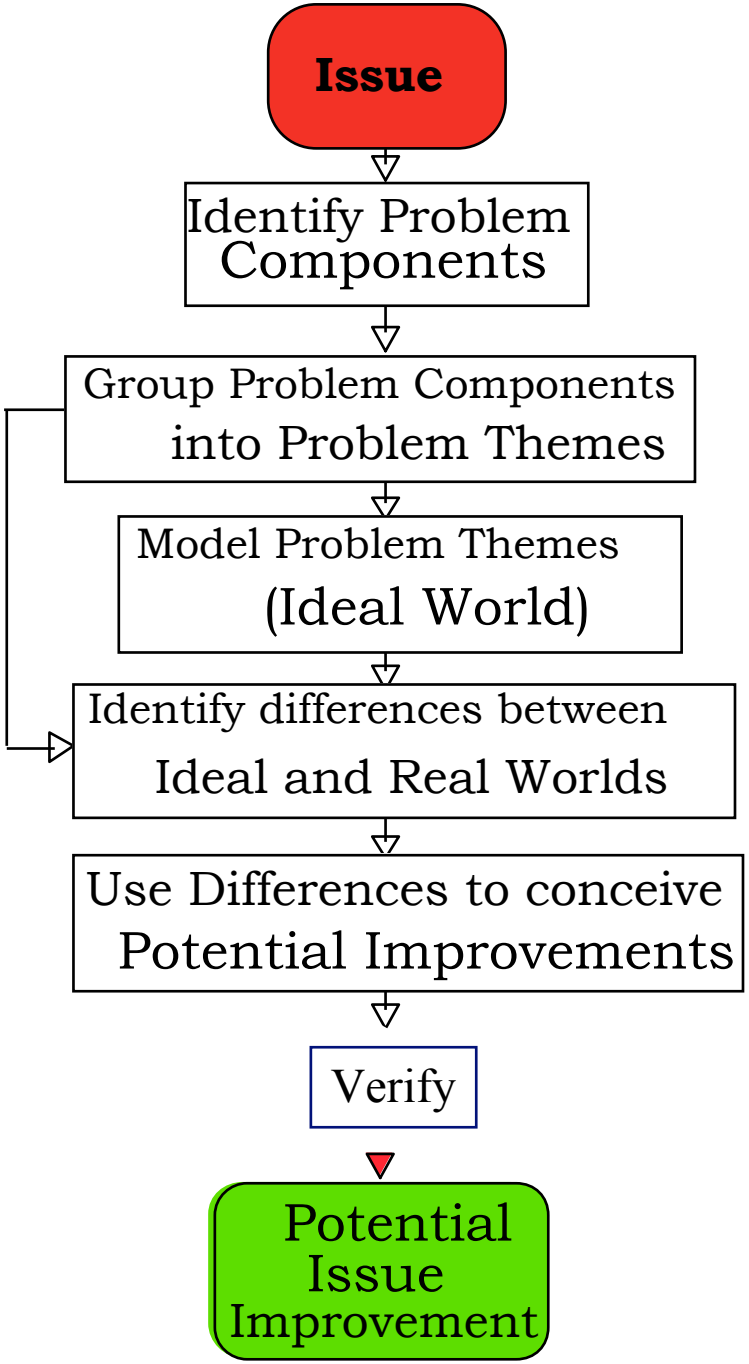
Problem-Solving Paradigms

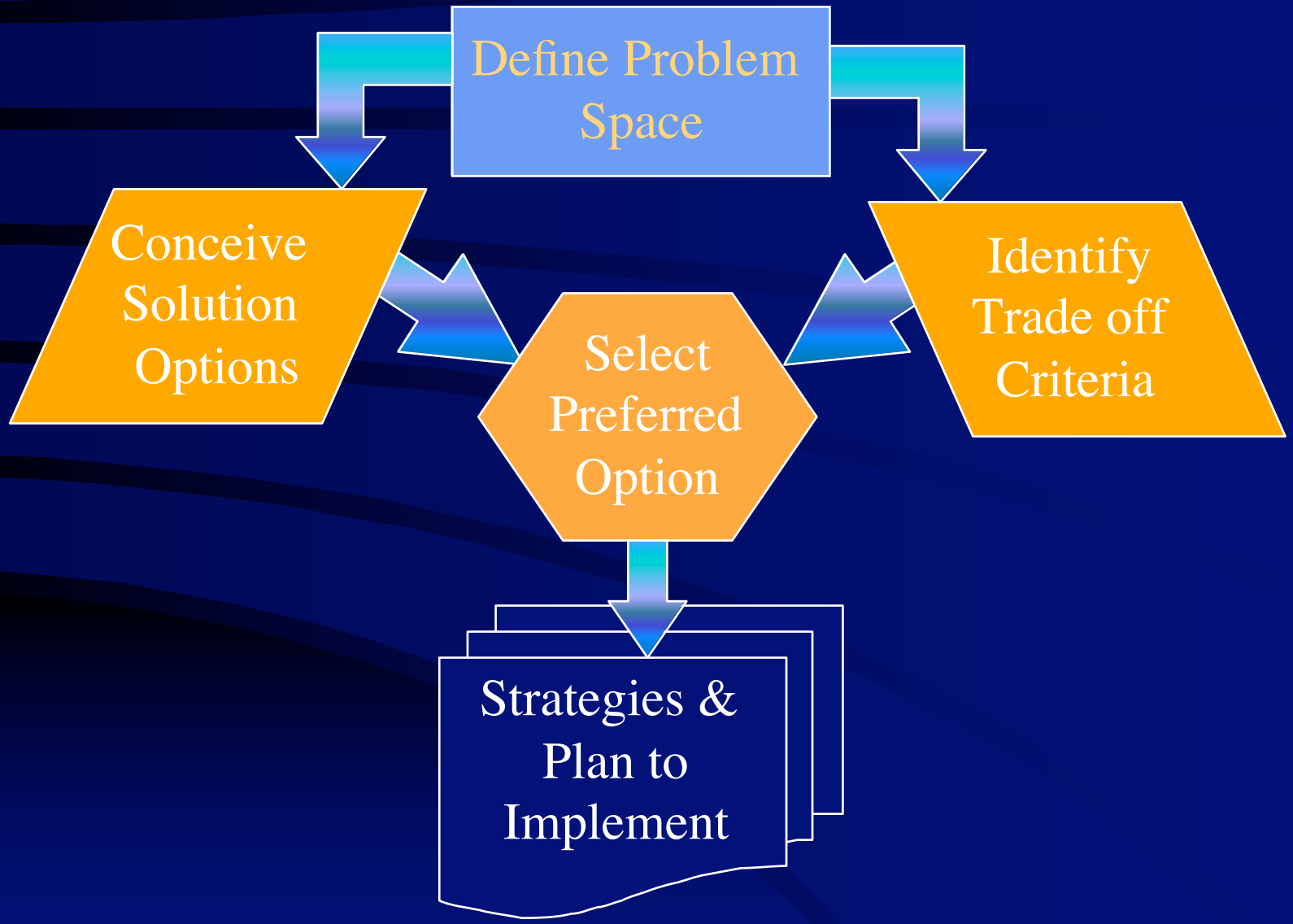
- Very few to choose between

1. General Problem Solving Paradigm (GPSP)
   - Popular in US
2. Systems Engineering Problem-solving Paradigm (SEPP)
   - More familiar in harder-systems contexts
   - Used worldwide by people who know nothing of systems engineering



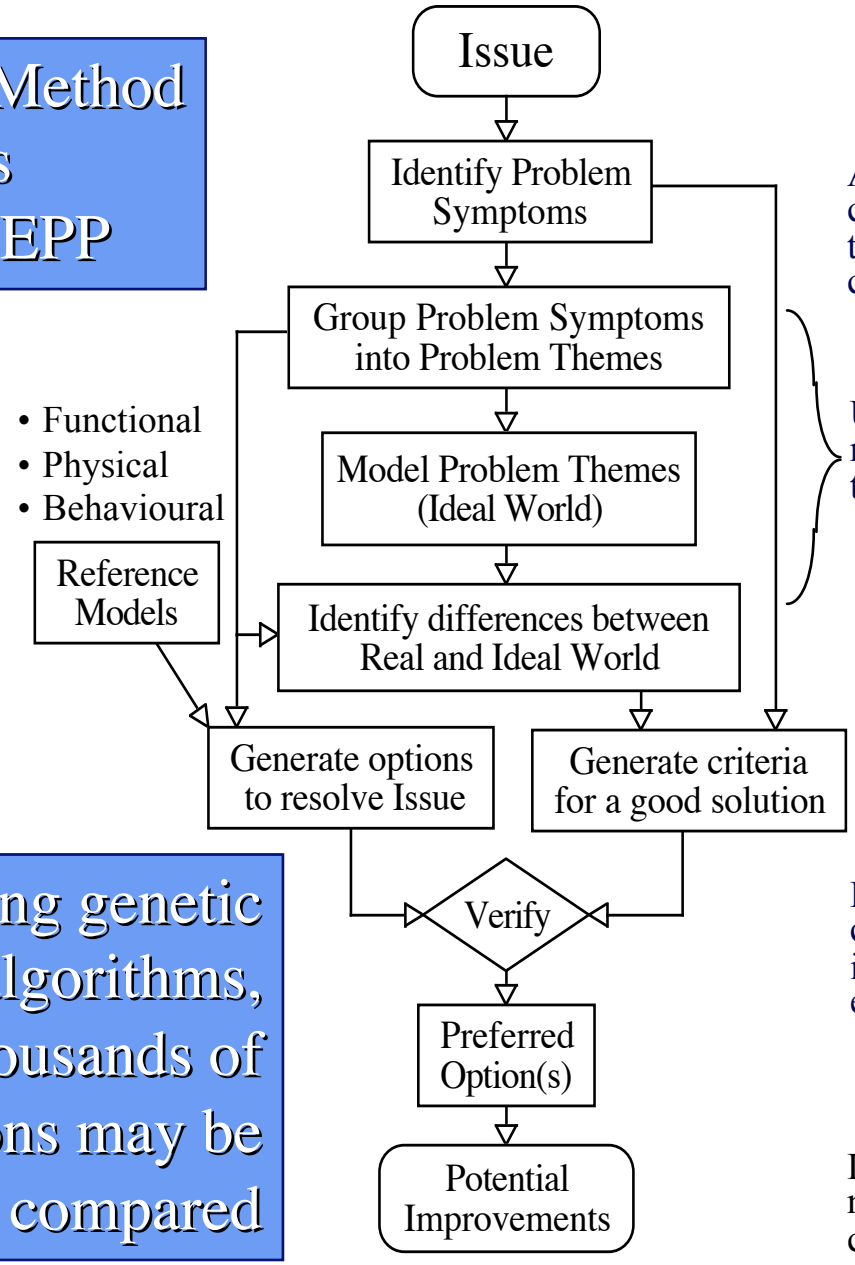
General Problem Solving Paradigm

Systems Engineering Paradigm



Rigorous Soft Method

Rigorous Soft Method combines GPSP and SEPP



Address **all** problem components to avoid (Forrester's) counterintuitive response

Use tools and methods to accommodate complexity

Ensure solution completeness—if any solution exists

Logical, consistent, but not necessarily culturally acceptable

Using genetic algorithms, hundreds/thousands of options may be generated and compared

What is the Rigorous Soft Method?

- A method for addressing problems or issues, using hierarchies of issue "symptoms"
  - Generates requirements for problem/issue resolution
- Employs techniques, tools and methods to:—
  - Elicit issue "symptoms"
  - Identify possible causes of those symptoms
  - Group possible causes to identify higher level "themes"
    - Hence "hierarchy"
  - Accommodate complexity, reduce entropy
- Addresses the most complex/abstract/obscure of issues
- A serious, heavyweight alternative to Checkland's SSM
- Eminently suitable for team-based working
- Mathematically provable (sic!)

Status of Soft Methods

- Estimate: tried, trusted, tedious, seldom used “in anger”
  - Not tool supported.
  - No overt reference model
- Soft Systems Methodology: current soft favourite, loose framework of steps, little guidance.
  - Lack of rigour believed by many to be its strength— “framework for thinking”.
  - Not tool supported.
  - Reference Model in abeyance
- Rigorous Soft Method: new, seeks rigour for soft problems. Developing successful case-study record.
  - Tool supported.
  - Reference Model invaluable

So, How Does RSM *Work?*

The GP Approach

- Visit to the doctor
  - "Doc, I don't know what's wrong, but I feel out of sorts…"
- Doc looks for symptoms
  - "What do you do, what has happened to you recently?"
  - checks for deficiencies, excesses, out of balances
    - urine, blood, electrolytes, sugar levels, etc.
    - spots, discoloration, temperature, bloodshot eyes, etc.
- Greater variety of symptoms, greater prospect of diagnosis
- Postulates potential causes for each symptom, then…
- …potential causes common to several symptoms
- Hence diagnosis from cause(s) common to many/all symptoms

RSM operates on similar lines

RSM—Seven Steps to…

Step 1. Appreciate broad area of concern

Step 2. Find the symptoms causing concern

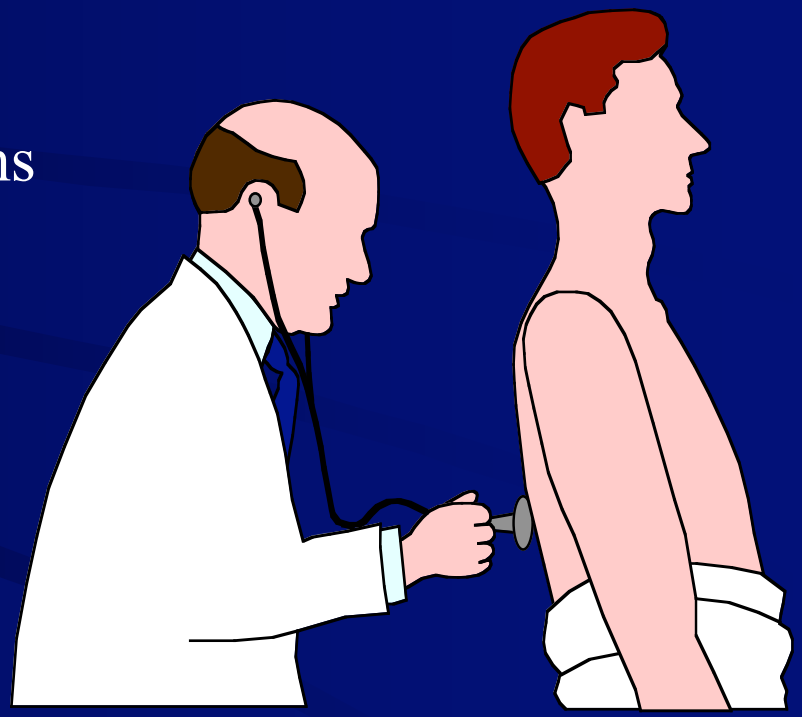
Step 3. Find suspect *implicit* systems

Step 4. Group suspect *implicit* systems into sets

Step 5. Highlight set deficiencies compared with ideal

Step 6. Propose requirements (remedy) for cure

Step 7. Check requirements (remedy) resolve all symptoms



Structure of RSM

- Made up from a number of simple techniques strung together
- Choice of techniques crucial to resolve vague issues:—
  - each technique must move the process forward
  - output from first must feed smoothly into second, etc.
  - none should eliminate useful information
  - each should encourage new ideas, understanding
    - especially that developing during the RSM process
- Whole must provide a clear audit trail
- Whole must exhibit rigour, i.e. clear, comprehensive, rationale
- Yet, whole must encompass eclectic viewpoints, information, cultures…

RSM Techniques—1

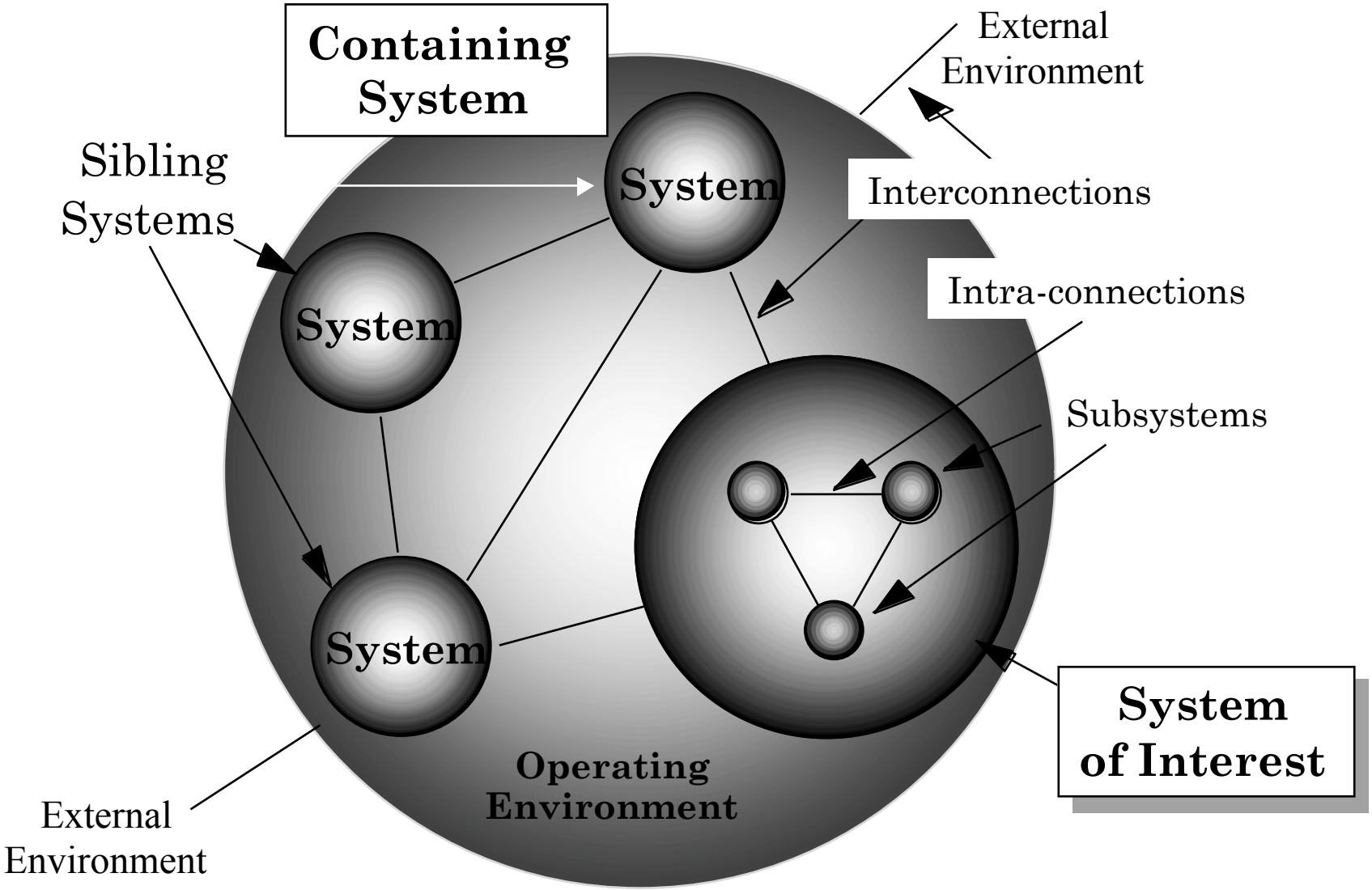
- System models—provides simple hierarchy framework
- "How-can-we?"—simply asking the right kind of question
- Cause-effect analysis—works from Issue symptoms back to (probable) causes
- Why-Why analysis—reduces superficial treatment of Issue symptoms
- Causal Loop Modelling—systems thinking technique—interrelates symptoms, promotes completeness
- POETIC—acronym for promoting completeness
- Dynamic Systems Modelling—object-oriented systems thinking, using computer simulation
- N2 and ©CADRAT—Organizational structure analysis and hierarchy shifting, with computer support
- System Diagramming—high-level presentation technique

RSM Techniques—2

- Each of the techniques is useful on its own
- Strung together, they provide a powerful suite of techniques for addressing the most complex of issues rigorously
- Other techniques can be plugged-in, with care, e.g. Nominal Group Technique, Interpretive Structural Modelling
- Warnings:—

1. It does not follow that there is always a resolution to an Issue
2. Using the full RSM takes time, patience and (ideally) a team of people with complementary backgrounds
3. Those unfamiliar with such techniques will experience culture shock on meeting them for the first time, therefore…
4. Do not show all your analysis to a customer, unless they either ask, or challenge your results

The "Poached Egg" System Model…



Contained and Containing

- Contained systems exist within a Container or Containing System
  - Contained systems referred to as siblings, Containing Systems as parents
- Better analogy—mother, father and children contained within Family Containing System
- Hard view places a system uniquely in a Container
  - module in sub-assembly, in assembly, in unit, in…
- Soft view allows "multiple simultaneous containment" in more than one Container
  - bus driver in bus, in social group within bus, in TGWU, in his/her family, in local church, in ethnic group. Bus driver's thoughts and actions may be influenced by any or all of these Containers.

Why is RSM different?

- Uses context-free, computer-based tools
  - retains “softness”, yet…
  - …can tackle large/complex problems
- Can be “proved” mathematically
  - raises confidence in soft rigour
- Highly traceable
- Works well with multi-disciplinary, multi-viewpoint teams
  - suitable for teams, syndicates, working parties, etc.
- Automatically develops team/individual briefing material

Where can RSM work?

- Intended for soft, works for hard, too
- Right up front, when it is difficult to get started and the wood gets in the way of the trees
- Where superiors/customers may demand justification,
  - e.g. spending public money
  - briefing superiors
- Where a group needs to reconcile differing viewpoints under time pressure

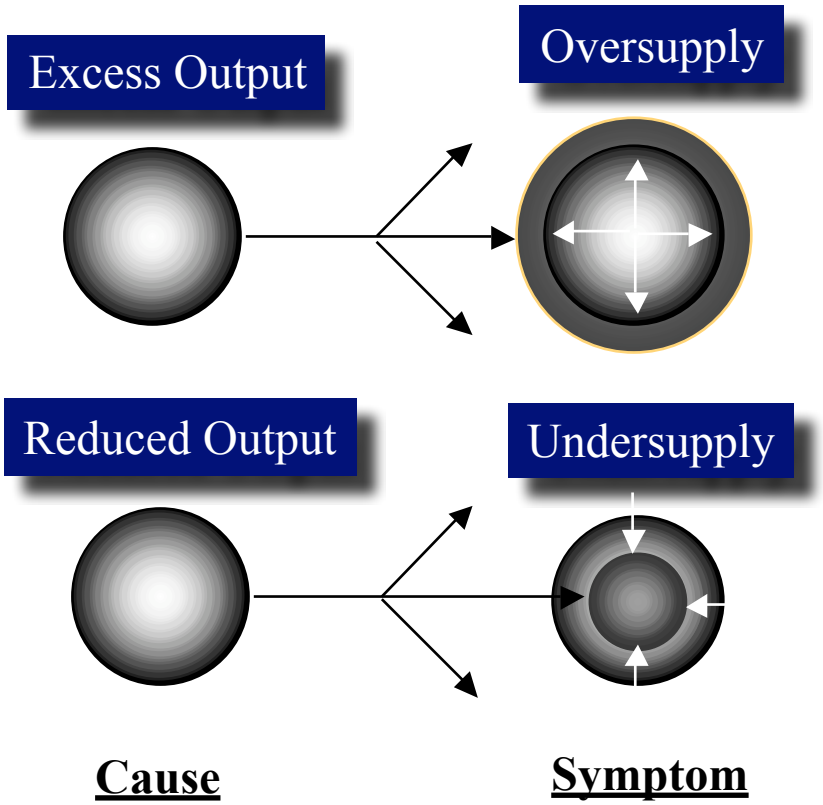
RSM Cons

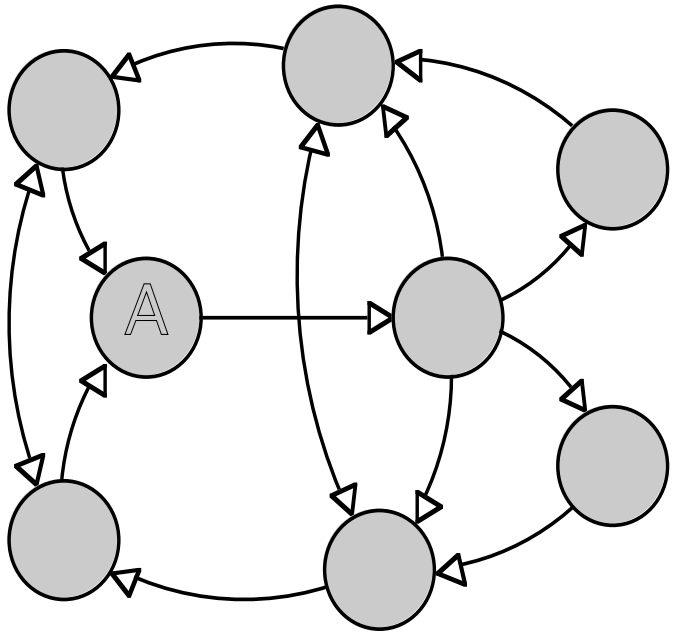
- Like the Estimate and SSM, takes practice
  - some users find modelling hard at first
- Can drag users into areas of little understanding
- No substitute for knowing your subject
  - experience of problem domain essential
- RSM helps users to understand requirements
  - it does not write the requirement, improve the situation, change behaviour, etc.
  - other methods essential to complement RSM

Getting started—finding Issue Symptoms

- Symptoms are indications of change from a previous, supposedly-satisfactory state
- Symptoms can be found by:—
  - asking questions, interviewing, from reports, statistics
  - observation
- Some symptoms arise from lack of co-operation (synergy) between the various people/parts in a complex system where, perhaps, co-operation previously existed
- Other symptoms arise from culture—people caught in the trap of their experience, unable/unwilling to see other viewpoints:—
  - MacGregor's Theory X and Theory Y

Symptoms Arise where the Problem Isn't





Q. If A changes its output, where will the symptom appear?

What causes symptoms?

- Symptoms often occur where the problem isn't(sic)
  - Pain in left arm from heart attack
  - Poor performance from lack of training
  - Poor reception from weak transmission
- Symptoms arise due to an imbalance between previously-balanced system pairs:—
  - Pain from imbalance between system for supplying blood and system for energising muscles
  - Poor performance from imbalance between system for setting training needs and system for training
  - Poor reception from imbalance between system for generating signals and system for receiving signals
- One symptom may arise from several causes/imbalances:—
  - Pain in left arm from imbalance between system for sensing pain and system for suppressing pain
  - Poor performance from imbalance between system for directing personnel and system for following directions
  - Poor reception from imbalance between system for amplifying signals and system for suppressing noise interference

The "How-can-we"s

- Symptom categories emerge according to question posed.
- "How can we…?" elicits perceived current barriers to improving group situation/performance/effectiveness, efficiency, quality, etc.
- "What do you think is wrong?" elicits parochial views, cultural perceptions, pet cures
- Responses convert to symptoms:—
  - "How can we become more efficient?"—perceived low efficiency
  - "How can we improve morale?"—perceived low morale
  - But—"I think that the management doesn't know what it is doing"—lack of confidence, low morale?
  - and—"I think we should change our suppliers—they're hopeless!"—pet cure, may be incorrect diagnosis, but worth following up?

The Five Whys

- Popular in Japan—ask why up to five times
- Why are you inefficient? Because we waste effort
- Why do you waste effort? Because we don't plan carefully
- Why don't you plan carefully? Because we are in too much of a hurry
- Why are you in too much of a hurry? We're trying to do too much with too few people in too little time
- Why are you trying to do too much…? We underestimate the amount of work needed to address tasks properly
- Real causes of inefficiency:—
- overstretched resources—imbalance between resource estimation and tasks

Locus of Possible Causes

- For any given symptom there may be several potential causes—generally, impossible to be sure
- Must—identify all possible causes, treat all as suspect—hence, “locus of possible causes”
- Later RSM steps sort probables from possibles

The Rôles of Causal Loop Modelling (CLM)

Rôle A: Possible causes of symptom arise in same overall system. CLM used to find relationships between possible causes. Seeking loop closure often reveals new factors—additional possible causes

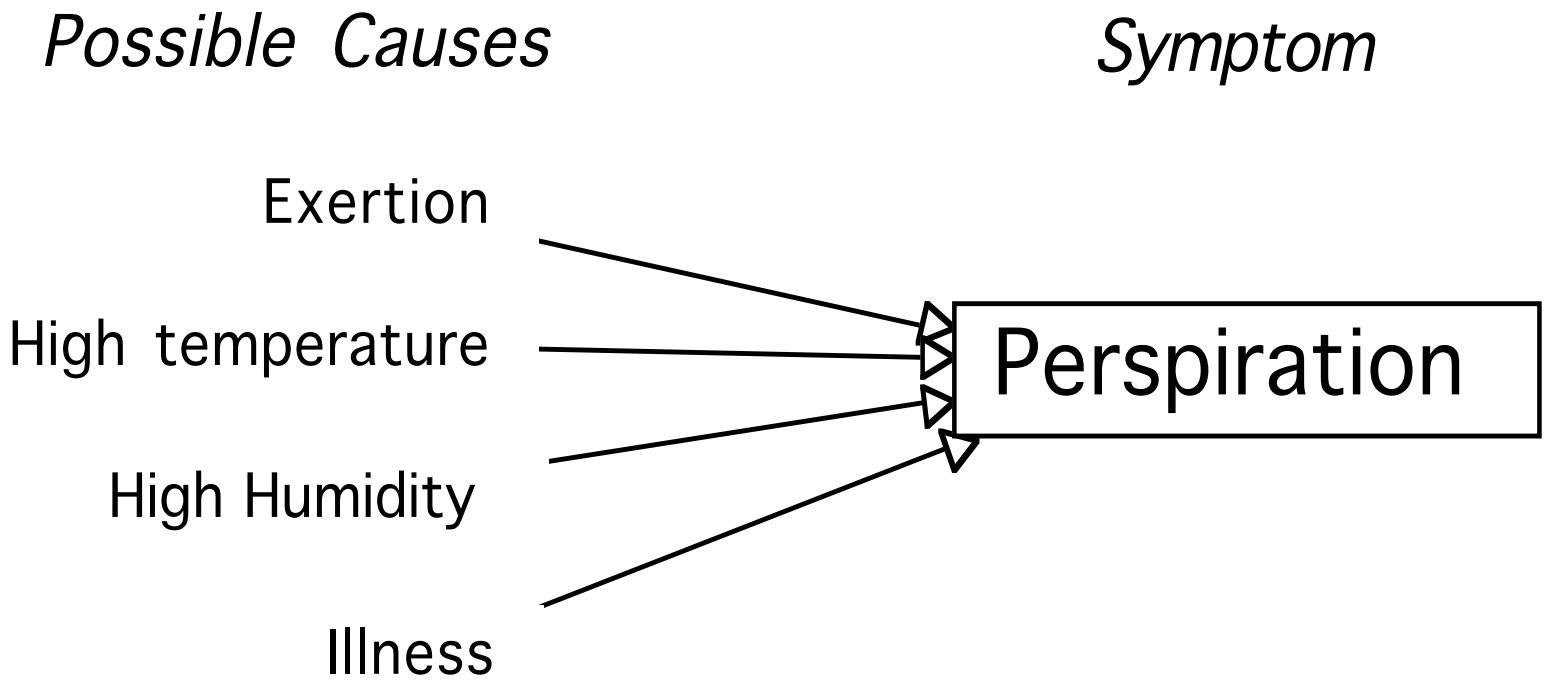
Rôle B: Possible causes of symptom represent potential problem areas—negatives. CLM developed without negative concepts, producing Ideal World model directly from possible causes.

Rôle C: CLM is ideal start point for iThink™/STELLA™ or similar dynamic modelling tools

Laundry Lists and CLMs

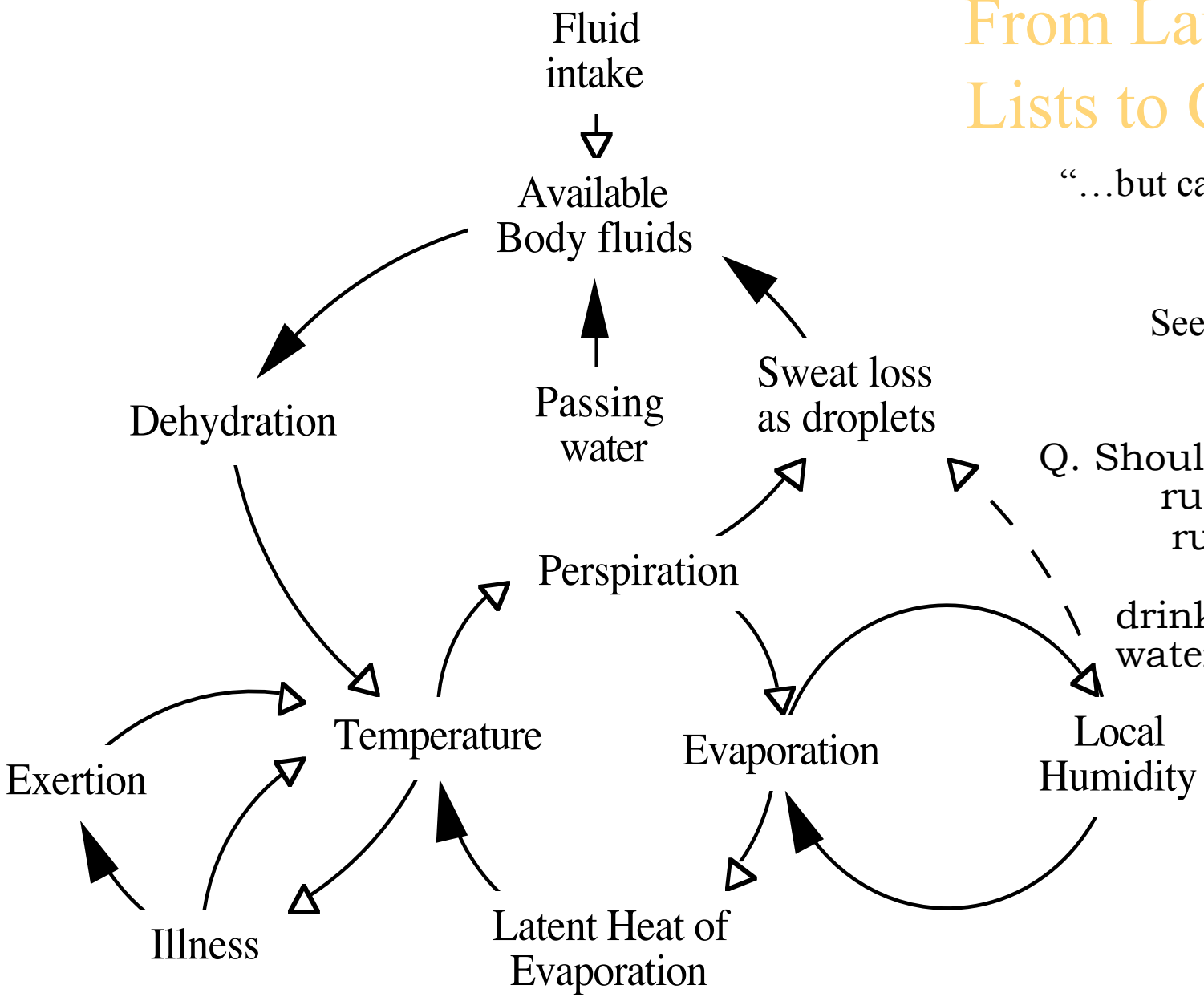
"We are trained to think in Laundry List fashion"

Barry Richmond, High Performance Systems Inc



Laundry List mentality helps generate possible causal factors, but the process misses out the relationships between the causes

From Laundry Lists to CLMs



"…but causal factors may not be mutually independent. Seeing relationships adds greatly to understanding"

Q. Should a marathon runner about to run in a humid climate drink more or less water than usual?

Creating CLMs

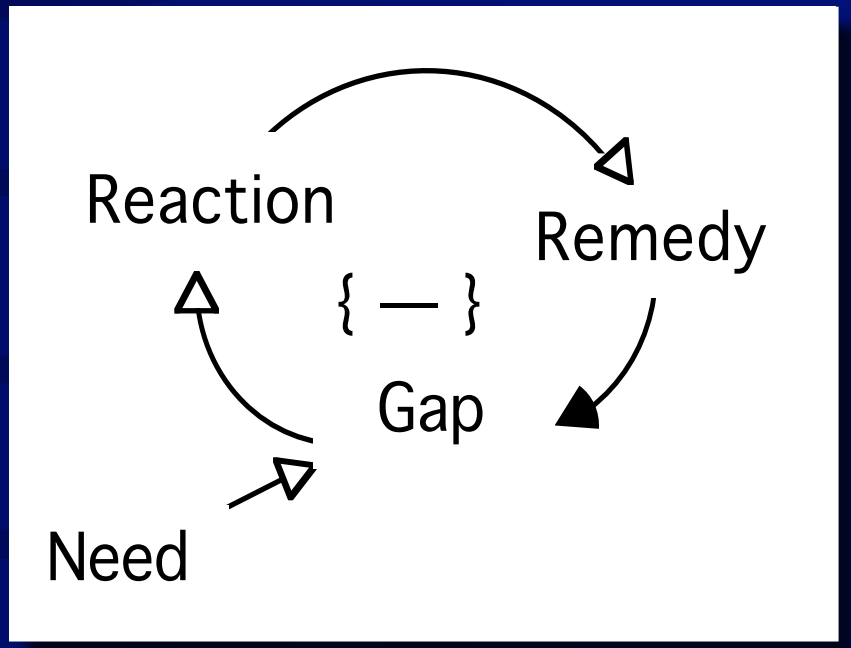
1. Identify the symptom
2. Establish a Laundry List of contributing factors, including organizational, technological, cultural, political, economic, etc., according to Issue
3. Develop a series of simple CLMs combining contributing factors, using nouns or noun phrases only and dropping any features from the Laundry List which suggest bias, such as ‘low’, ‘heavy’, ‘poor’, ‘hot’, etc.
4. Integrate the set of simple CLMs into a fuller single version, including the Entity to be modelled.

Archetypal CLM—1

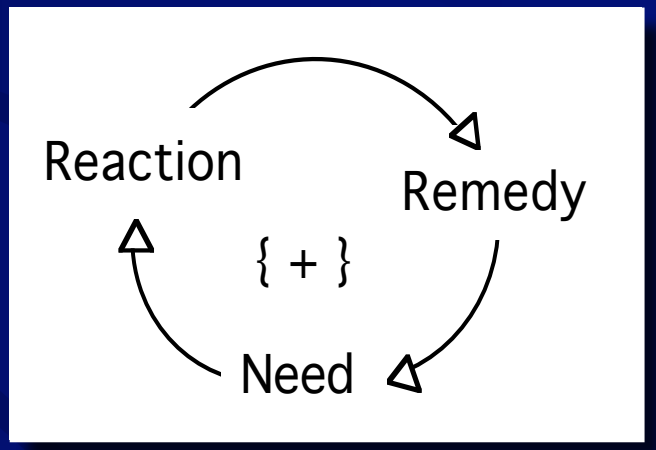
Often a good way to start when addressing requirements.

Need is perceived as a shortfall, or gap (which can be excess as well as shortfall)

Need creates some reaction—management response, complaint—which results in a proposed remedy, which begins to close the gap (black arrow-head). As presented, a negative feedback, or control, concept…

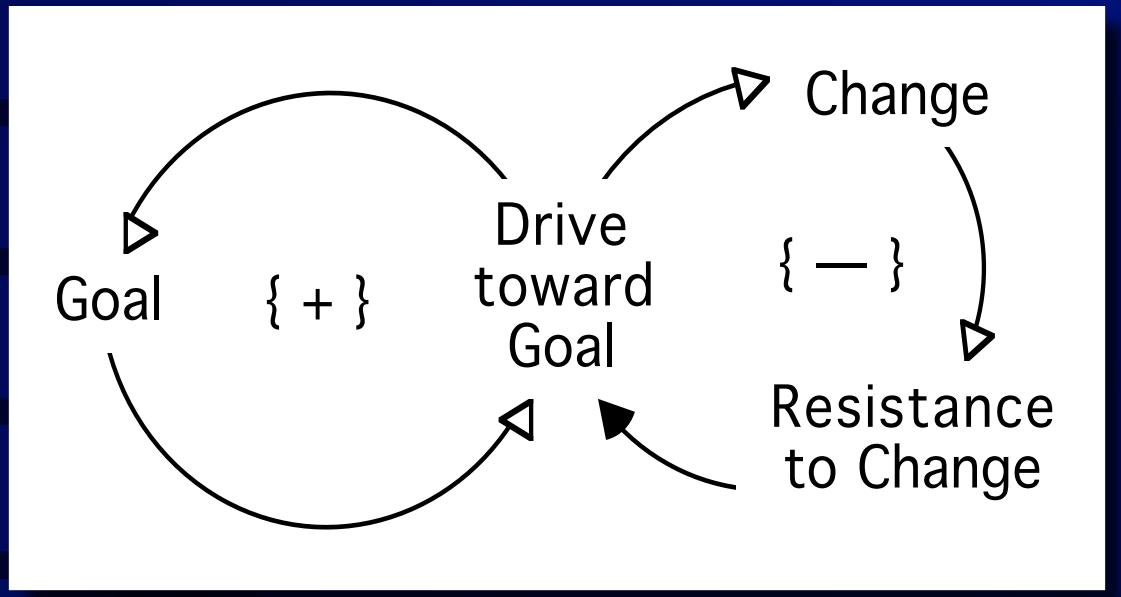


…but equally valid as a positive feedback loop in which case it presents a continual self re-inforcing loop, able to spin up—or spin down!



Archetypal CLM—2

after Peter Senge, *The Fifth Discipline*

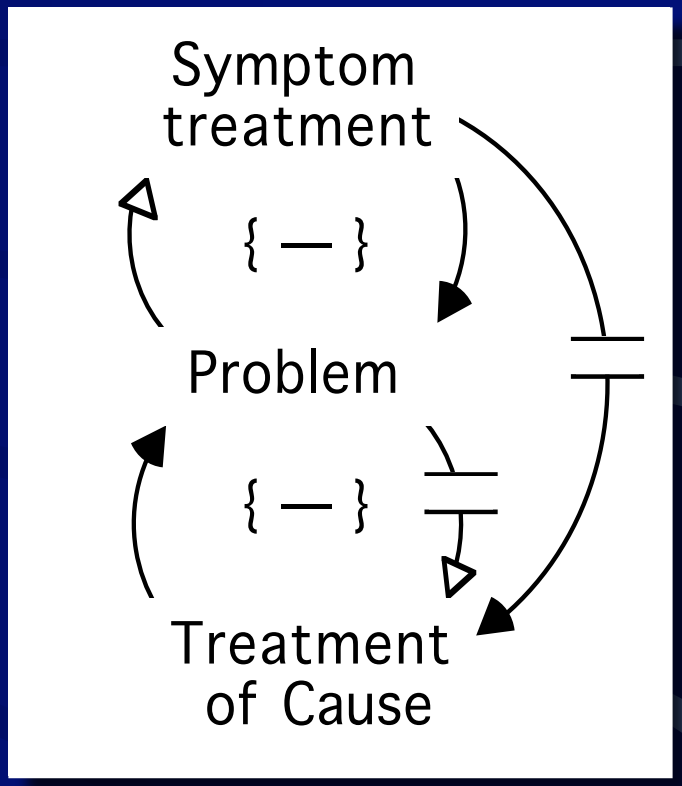


- Classic resistance to change
- Best seen as a basis for explaining organizational behaviour

Archetypal CLM—3

after Peter Senge, *The Fifth Discipline*

- Upper loop represents treating the symptoms rather than the underlying cause
- Lower loop invokes in-depth treatment of the underlying cause, but only after some delay—represented by the parallel lines—and expense needed to do the job properly
- Outside connection shows that effort expended on treating symptoms detracts from effort available to treat real cause. i.e. management short-termism



Land Force Capability

Extract from the Washington Business Herald Times, April 1st, 2004

MOJAVE MANEUVERS

The rise of terrorism is a cause for concern, not least because it is almost impossible to say where they will strike next. However, it would be foolish to concentrate on the terrorist threat to the exclusion of conventional warfare.

Proliferation of nuclear capability seems to be ongoing and inevitable. As with terrorism, however, to overly-concentrate on the threat of nuclear warfare would be to offer a potential enemy a so-called "free ride" in the conventional warfare arena.

It is not as though the West has conventional warfare "sown up." There are major arenas around the world where the US, for instance, would find it difficult to operate. One such is the desert, and it may not be without significance that we see DARPA, the US Defense Advanced Research Projects Agency, hosting a race between robot vehicles across the Mojave Desert. Why, one asks, would they be so interested in such an activity as to offer significant prizes? They are not renowned for their altruism.

So, US forces are faced with a shortfall in capabilities when it comes to land warfare over large open areas: deserts, tundra, plains, etc. There is plenty of room for potential enemies to raise, operate, maneuvre and hide sizeable forces. Interestingly, a number of such areas are in regions not too friendly to the US.

The US has a particular problem when it comes to casualties, too. The US public does not like "body bags," and they soon lobby their politicians if even one casualty arises. While 9/11 may have changed circumstances somewhat, casualties are still a major issue.

Desert conflict can be cripplingly difficult on man and machine: the second world war showed that in N. Africa, where Rommel and Montgomery faced off. Rommel was the proponent of the *blitz krieg*, while Montgomery was more in the mould of the set piece battle exponent. Neither party had it all their own way. Seemingly, neither strategy was dominant, at least not in that conflict.

Continued:

Land Force Capability

From previous page

It would be comforting to think that such arenas would find employment for existing weapon systems. The evidence suggests otherwise however. Our tanks and personnel carriers do not like desert operations: they overheat as the filters clog with sand; they consume enormous amounts of energy to keep their occupants cool; they get stuck in deep sand and need to be pulled out.

Communications can be difficult, too, with thermal inversions playing havoc with h.f. radios. Visual sights can be upset by heat shimmer and mirages. Radar has problems, too, when it has to be operated from vehicles on the move in undulating country; even the best radar may not work too well when at the bottom of some desert *wadi*.

Altogether, it has to be said that the problems facing the military in such hostile circumstances are more akin to those facing a naval task force that a conventional army land force. Perhaps the army thinktanks should catch up with their naval colleagues and compare notes!

There will always be a money issue when it comes to defense. One positive aspect of an otherwise forbidding 9/11 experience is that the arguments against defense spending are more muted than before. On Capitol Hill the question seems to be more about the risks of not spending, than of the expense *per se*.

When asked about the need for a new kind of open land force capability, Paul Weinhard did not confirm the need. Significantly, perhaps, he did not deny it either.

The smart money, then, is observing the significance of the events in the Mohaje Desert, and is forecasting an announcement of a new defense capability requirement within the next administrative period. Just what that new capability will be is anyone's guess. Our guess is that the winners of the Mojave competition will have a head start on the competition, and that robotic vehicles operating in deserts may have something to do with it!

Task

- The passage contains symptoms of an issue
- Identify what you perceive as the issue
- Identify symptoms within the passage, where a symptom is some change from a previous state perceived as satisfactory
- Review your symptoms and the issue.

Looking for Symptoms

Initial view of Issue: *"concern over US military capability when operating around the world in desert, tundra and other open arenas"*

1. There are major arenas around the world where the US, for instance, would find it difficult to operate.
2. DARPA, hosting a race between robot vehicles across the Mojave Desert
3. Shortfall in capabilities when it comes to land warfare…open areas: deserts, tundra, plains, etc. in regions not too friendly to the US
4. The US has a particular problem when it comes to casualties, too. The US public does not like "body bags"
5. Seemingly, neither strategy was dominant, at least not in that conflict
6. …existing weapon systems. The evidence suggests otherwise however
7. Communications can be difficult, too…visual sights can be upset… Radar has problems
8. …problems facing the military in such hostile circumstances are more akin to those facing a naval task force
9. …money issue…risks of not spending
10. new defense capability requirement within the next administrative period

- Perceived US military limitations in open land warfare
- Implied robot vehicle solution
- US political issue with casualties
- Uncertainty over desert operations strategies
- Perception that existing weapon systems unsuited to desert operations
- Communications, visual sights, radar - among problem systems
- Perception of military land situation being akin to naval operations at sea
- Perceived threat likely to overcome financial inhibitions
- Political urgency to attain new capability

Next Step…

- Take each symptom in turn
- Identify possible causes, using pejorative terms,
  - e.g. “poor,” “lack of,” “inability to,” etc.
- From list of possible causes, develop causal loop models, but drop the pejoratives
- Creates “ideal world” representation of processes and systems

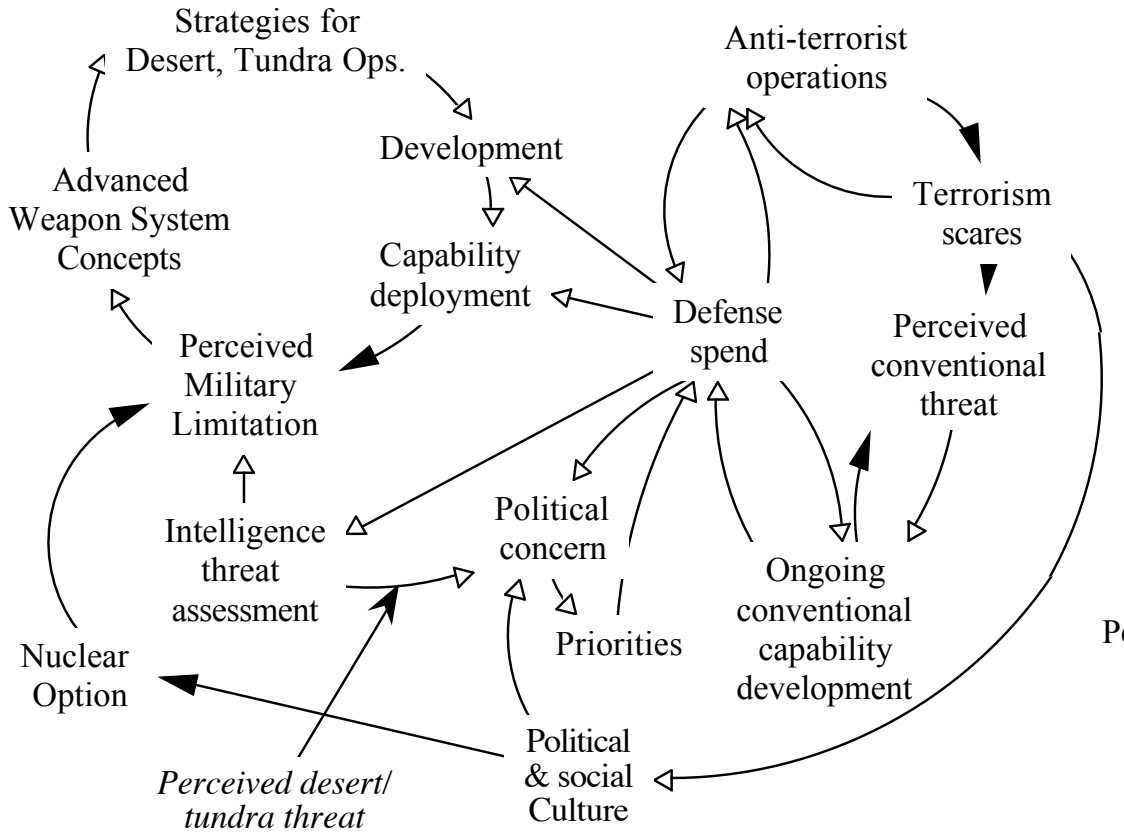
Politics
Organization
Economics
Technology
Inertia/Inactivity
Culture

Landry List of Possible Causes

Symptom

Lack of recent open land warfare experiecne
Current weapon systems lack desert terrain capabilities
Poor Intelligence about potential enemy capabilities
Recognition that nuclear option inappropriate against conventional enemy
Concern over terrorism scares "taking eye off the ball" of conventional warfare

→ Perceived US Military Limitation



Imbalanced Systems

System for…		*System for…*
Desert Op. Strategies	↔	Advanced WS Concepts
Advanced WS Concepts	↔	Perceived Mil. limitations
Perceived Mil. limitations	↔	Capability Deployment
Capability Deployment	↔	Developing capabilities
Developing capabilities	↔	Desert Op. Strategies
Perceived Mil.limitations	↔	Int.threat Assess.
Int.threat Assess.	↔	Political concern
Political concern	↔	Defense Spend
Defense Spend	↔	Development
Defense Spend	↔	Capability Deploy.
Defense Spend	↔	Int.threat Assess.
Political concern	↔	Pol & Soc culture
Pol & Soc culture	↔	Reaction to terror

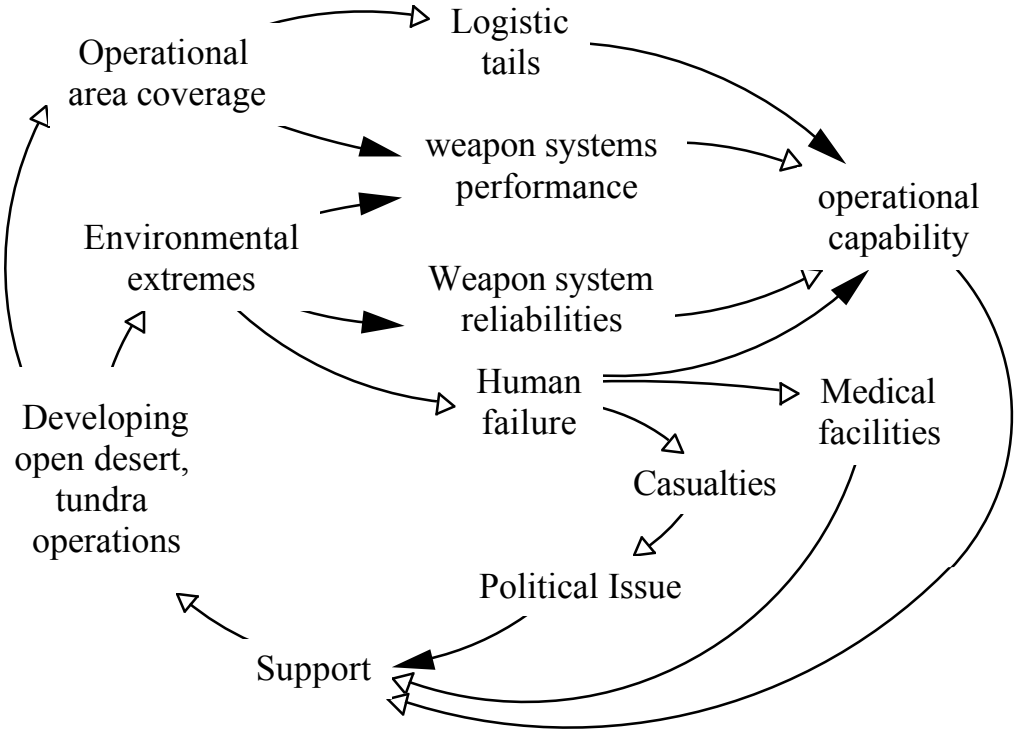
Politics
Organization
Economics
Technology
Inertia/Inactivity
Culture

Landry List of Possible Causes

Extensive, open, harsh, terrain
Unreliable current systems
Restrictions on strategies imposed by current weapons
Need for large, diverse forces
Long logistics tails
Protracted operations
Potential for many casualties

Symptom

Inadequate open desert land force capability

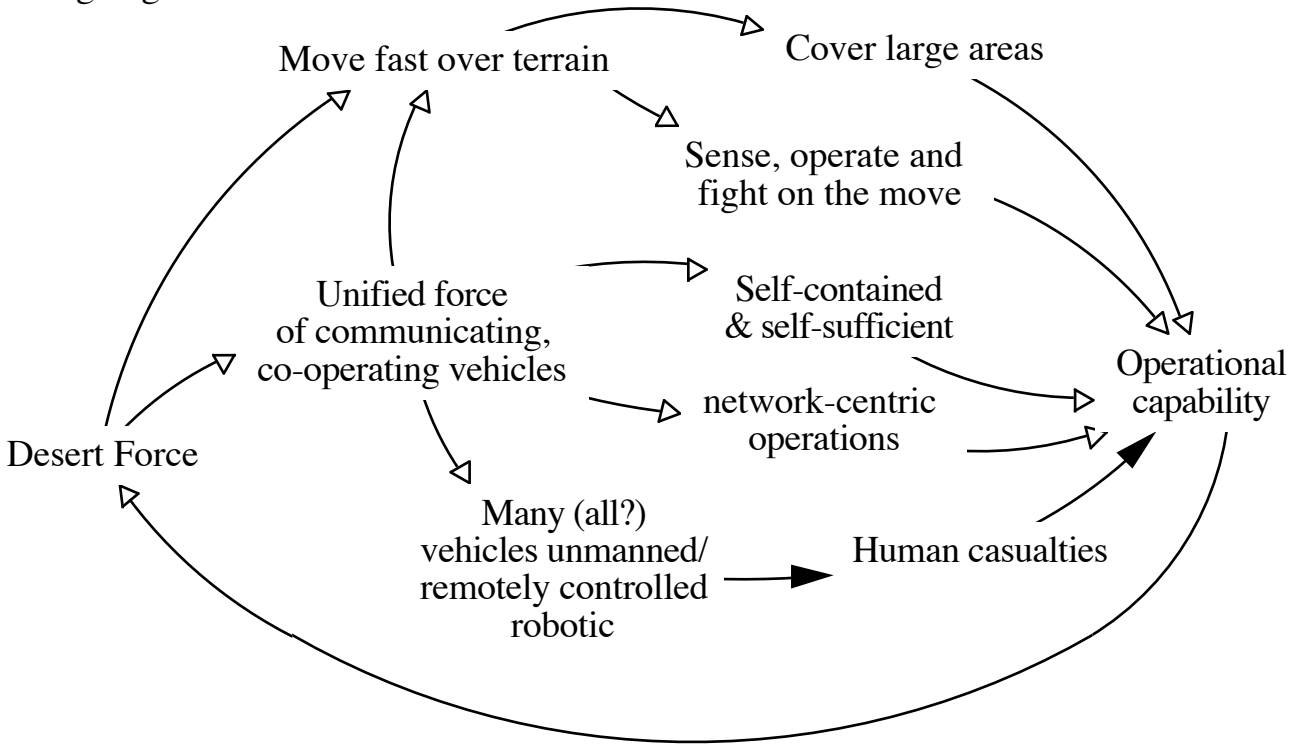


Imbalanced Systems

System for…		*System for…*
Developing desert operations	↔	Covering large areas
Covering large areas	↔	WS performance
Covering large areas	↔	WS Reliabilities
Covering large areas	↔	Logistic tails
WS performance	↔	Achieving Op. Capability
Human performance	↔	Achieving Op. Capability
Achieving Op. Capability	↔	Developing desert operations

System Solution Concept Factors

1. Uncertain warfare strategy. there is an ongoing concern about the relative mertis of "positional warfare" and maneuver warfare (e.g. *blitzkrieg*.)
2. Competitions to race robotic vehicles across the Mojave Desert suggest that the ideal strategy, one of being able to adopt either positional, or maneuver warfare, or hit and run, etc., has been inhibited by the inability to operate quickly and without loss of life over large, inhospitable tracts.
3. Current technologies clearly have limitations in extreme environments
4. The concern over casualties is ongoing, and could threaten US abilities to defend itself effectively. A solution with few, or even zero casualties would be attractive…
5. There are very large, open, sparsely-populated areas around the world
6. The idea that land operations could be likened to naval operations, with thee ide, open areas equating to the oceans, is intriguing.



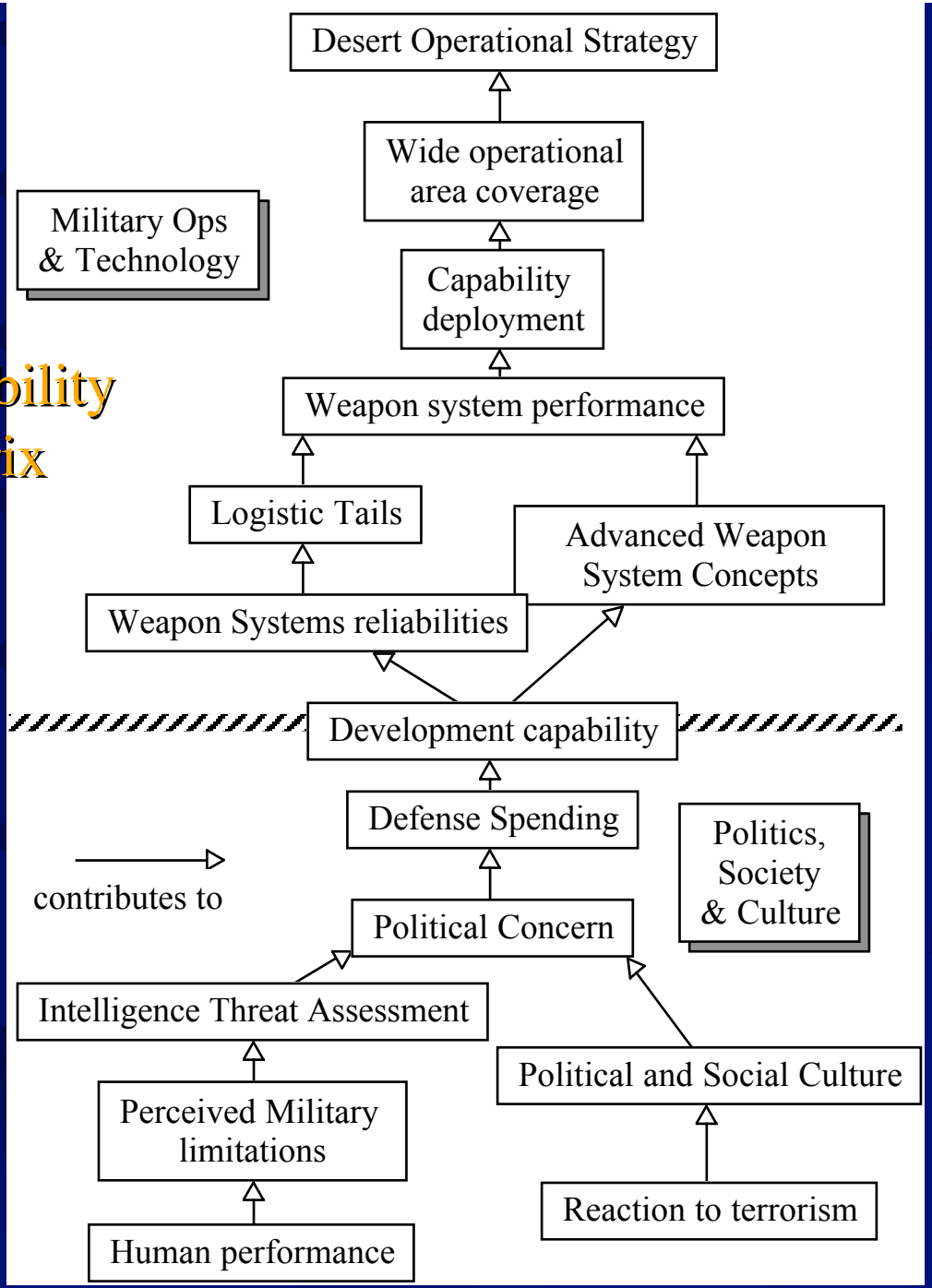
Consolidated List of Implicit Systems in Imbalance

	Implicit System for…		Implicit System for…
Organization & Technology	Developing desert operational strategies	↔	Formulating advanced weapon system concepts
	Formulating advanced weapon system concepts	↔	Perceiving military limitations (Intel)
	Perceiving military limitations	↔	Deploying military capabilities
	Deploying military capabilities	↔	Developing military capabilities
	Developing military capabilities	↔	Desert operational strategies
	Perceiving military limitations	↔	Intel threat assessment
Politics, culture and Economics	Intel threat assessment	↔	Political concern
	Political concern	↔	Defense Spend
	Defense Spend	↔	Developing military capabilities
	Defense spend	↔	Deploying military capabilities
	Defense spend	↔	Intel threat assessment
	Political concern	↔	Political & Social Culture
	Political & Social Culture	↔	Reaction to Terrorism
Desert Capabilities	Developing desert operations = developing military capabilities	↔	Covering large areas/tracts/tundra
	Covering large areas/tracts/tundra	↔	Weapon systems performances
	Covering large areas/tracts/tundra	↔	Weapon systems reliabilities
	Covering large areas/tracts/tundra	↔	Logistic “tails”
	Weapon systems performances	↔	Achieving operational capability = Deploying military capabilities
	Human performance (in desert, tundra, etc.)	↔	Achieving operational capability = Deploying military capabilities
	Achieving operational capability = Deploying military capabilities	↔	Developing desert operations = Developing military capabilities

Desert Ops
ISM "Rich Picture"

Reachability Matrix															
Hum Perf	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1
Rct terror	2	0	1	0	1	0	1	1	1	1	1	1	1	1	1
Perc Mil Lim	3	0	0	1	0	1	1	1	1	1	1	1	1	1	1
P&S Culture	4	0	0	0	1	0	1	1	1	1	1	1	1	1	1
Int Thrt Ass	5	0	0	0	0	1	1	1	1	1	1	1	1	1	1
Pol Concern	6	0	0	0	0	0	1	1	1	1	1	1	1	1	1
Def Spend	7	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Dev Capab	8	0	0	0	0	0	0	0	1	1	1	1	1	1	1
WS reliab	9	0	0	0	0	0	0	0	0	1	0	1	1	1	1
Adv WS Conc	10	0	0	0	0	0	0	0	0	0	1	0	1	1	1
Log Tails	11	0	0	0	0	0	0	0	0	0	0	1	1	1	1
WS perf	12	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Capab Deploy	13	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Area cover	14	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Des Op Strat	15	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Reachability Matrix



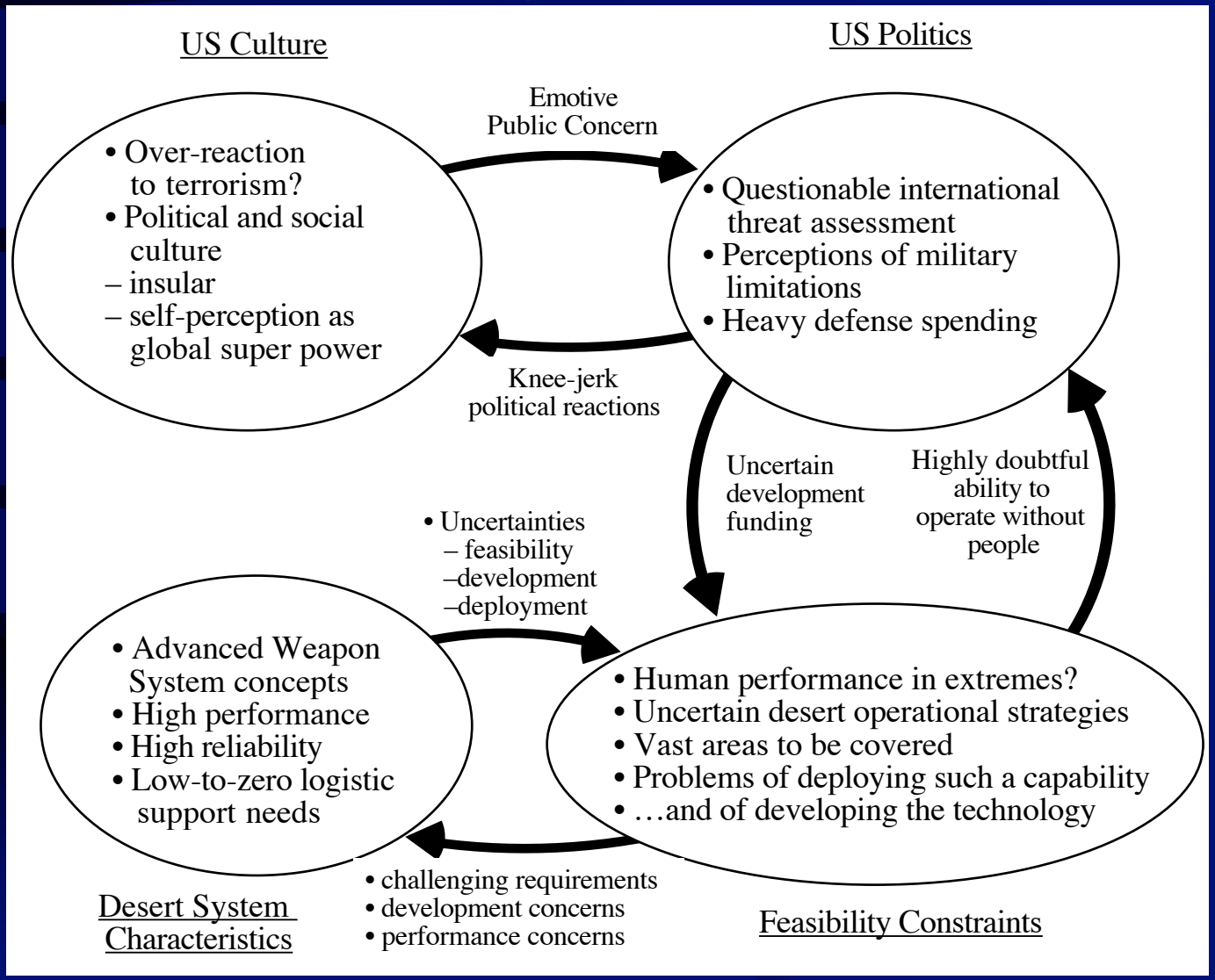
N2 with Missing Cell

Hum Perf	1	A	1								?			
Perc Mil Lim	2	1	C	1										
Int Thrt Ass	3		1	E			1							
Rct terror	4				B	1								
P&S Culture	5				1	D	1							
Pol Concern	6			1		1	F	1						
Def Spend	7						1	G	1					
Dev Capab	8							1	H	1	1			
WS reliab	9								1	I		1		
Adv WS Conc	10								1		J		1	
Log Tails	11									1		K	1	
WS perf	12										1	1	L	1
Capab Deploy	13	?											1	M
Area cover	14													1
Des Op Strat	15													

N2 "Rich Picture"

| | | |

SID - the Systems Interaction Diagram – a Really Rich Picture



Two themes within the Issue.

- So, there are four "systems" and - at least - two themes within this issue:
  - The political, social and cultural theme(s), and the…
  - …advanced technological solution theme
- The two themes are closely interwoven
  - "War is an extension of politics" - Clausewitz
  - Specifically, the US has declared war on terrorism
    - Consistent with US self-imposed task of converting the world to democracy
    - Potentially reduces emphasis on conventional warfare
    - Restricts advanced development—a US "silver bullet"
    - Bad for some sectors of US/international defense business
  - The new, perceived need could be genuine - could also be designed to promote US advanced technology industries
    - C.f. NASA finding "Martian rocks, with life," in Antarctica?
- Note: US Defense pays for Defense Intelligence. No threat, no funds? If your were in Intelligence, what would you do?

But, Is it *Real?*

- It is not impossible that the idea of some robotic force roaming the deserts and tundra of the world, taking on "the bad guys," is an entire fiction.
- Such a fiction would serve to reinforce belief in US military and technological domination, both at home and abroad.
- Cynical?

Quad et…

- So far, we have identified, defined bounded and explored the problem space and the Issue
- The major part of the Issue is concerned with US politics and US social and political culture—a point not obvious when we first read the passage
- From here on in, we will look towards the solution system - the new mobile land force - and leave the politics to the politicians(!)