Evaluating C2 Systems

Fechner's Law of Utility

"the magnitude of a subjective sensation increases proportional to the logarithm of the stimulus intensity"

U = K Log S

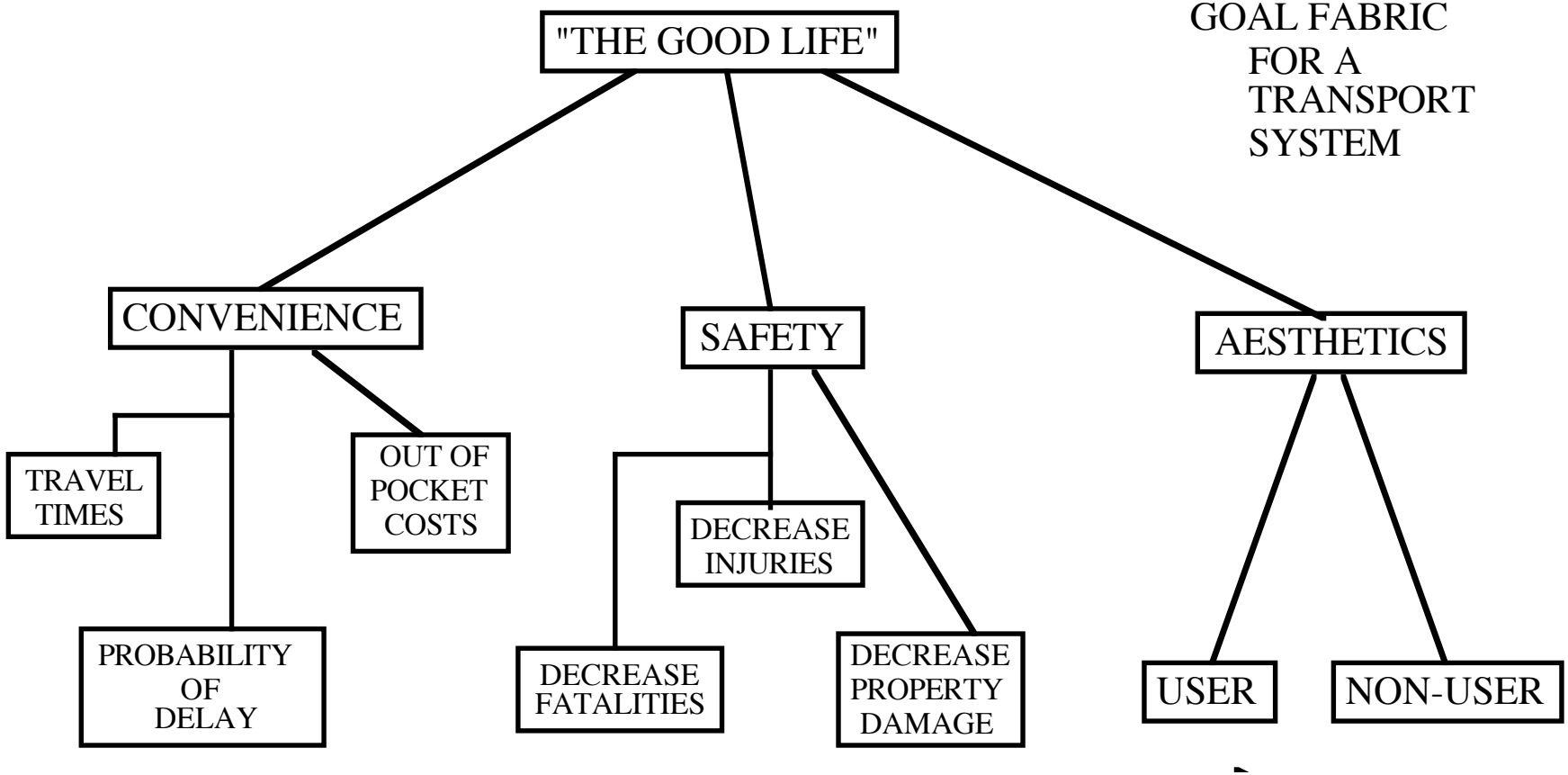
S is the intensity of the stimulus

If you are starving the value of one loaf may be enormous.

If you already have nine loaves, the value of one more loaf may be slight…

Fechner's law, or the Weber-Fechner Law have to be borne in mind when evaluating C3 systems, particularly in respect to the value of (more) information

Manheim & Hall's Approach



Used in the determination of a US policy towards SSTs

Components of a Sound Project Evaluation Process

A. A clear notion of project objectives.

B. A rational method of identifying project features contributing to those objectives

C. A rational method of identifying project features detracting from those objectives

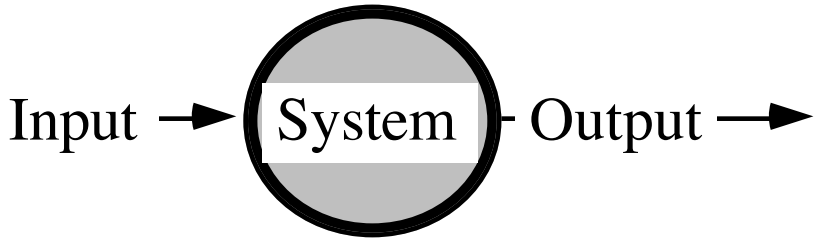
D. A means of relating contributing and detracting features

Further, since choices have to be made between options:—

E. A means for comparing options to determine the "best"

F. An absolute reference to determine whether "best" is good enough or too good in absolute (rather than simply in relative) terms.

Efficiency as an Evaluation Measure



Efficiency = (Output / Input) x 100%

Efficiency is an "internal" view of a system. There are no standards by which to judge whether a given efficiency is good, bad or indifferent

Nature produces seemingly v. low efficiencies—0.1—3% for plants

Maximum rate of doing work occurs at 50% efficiency per process — several processes in series reduces overall efficiency to low figures, where speed of reaction is important

Queuing Theory supports 'low' efficiencies, to reduce queue lengths and waiting times. e.g. simple FIFO queue has mean Q length of '1' when

$$\rho = \lambda/\mu = 0.5$$

Evaluating Effectiveness

Effectiveness is an external measure of a System—how much impact (effect) it has on other systems.

Procedure:—

- Establish an ideal model of the system in its environment, interacting with other systems in that environment—the 100% state.
- Compare the proposed or existing system(s) against the model to identify and highlight differences.
- Aggregate the differences according to some schema to produce an overall figure of merit for each candidate system

An Effectiveness Template

D K Hitchins

DESIGN DRIVERS / EMERGENT PROPERTIES		SOLUTION OPTIONS		
		OPTION A	OPTION B	Option C
Performance	Capability			
	Behaviour			
Availability	Reliability			
	Maintainability			
Adaptability	Flexibility			
	Expandability			
Interoperability	Communication			
	Protocol			
Usability	Human Factors			
	MMI / HCI[3]			
Survivability	Avoidance of Detection			
	Self Defence			
	Damage Tolerance			
Security	Data			
	Physical			
Safety	Operation			
	Maintenance			
	Development			

		Display System Options (Example Only)					
Design Drivers	Sub-Drivers	1 Alpha	2 Alphas	1 Alpha+ 1 Graphic	1 Graphic	2 Graphics	Row Sums
Utility	Performance	5	4	2	3	1	15
	Fallback	4.5	2	2	4.5	2	15
Availability	Reliability	4	2	3	5	1	15
	Maintainability						
Adaptability	Flexibility	5	4	2	3	1	15
	Expandability						
Interoperability	Communications						
	Protocols						
Usability	Human Factors	5	3	4	2	1	15
	MMI	3	4	5	1	2	15
Survivability	Avoidance of Detection						
	Self Defence						
	Damage Tolerance	4.5	3	2	4.5	1	15
Security	Data						
	Physical						
	Rank Sum	31	22	20	23	9	105
	Rank Order	5th	3rd	2nd	4th	1st	

Coefficient of Concordance = 0.5102
Probability of Random Occurrence < 1%

Rank Matrix Analysis

Derek Hitchins

N.B. Ranking much easier /more objective than Weighting and Scoring

Without Cost, Most Effective =Most Expensive

Effectiveness as a Measure

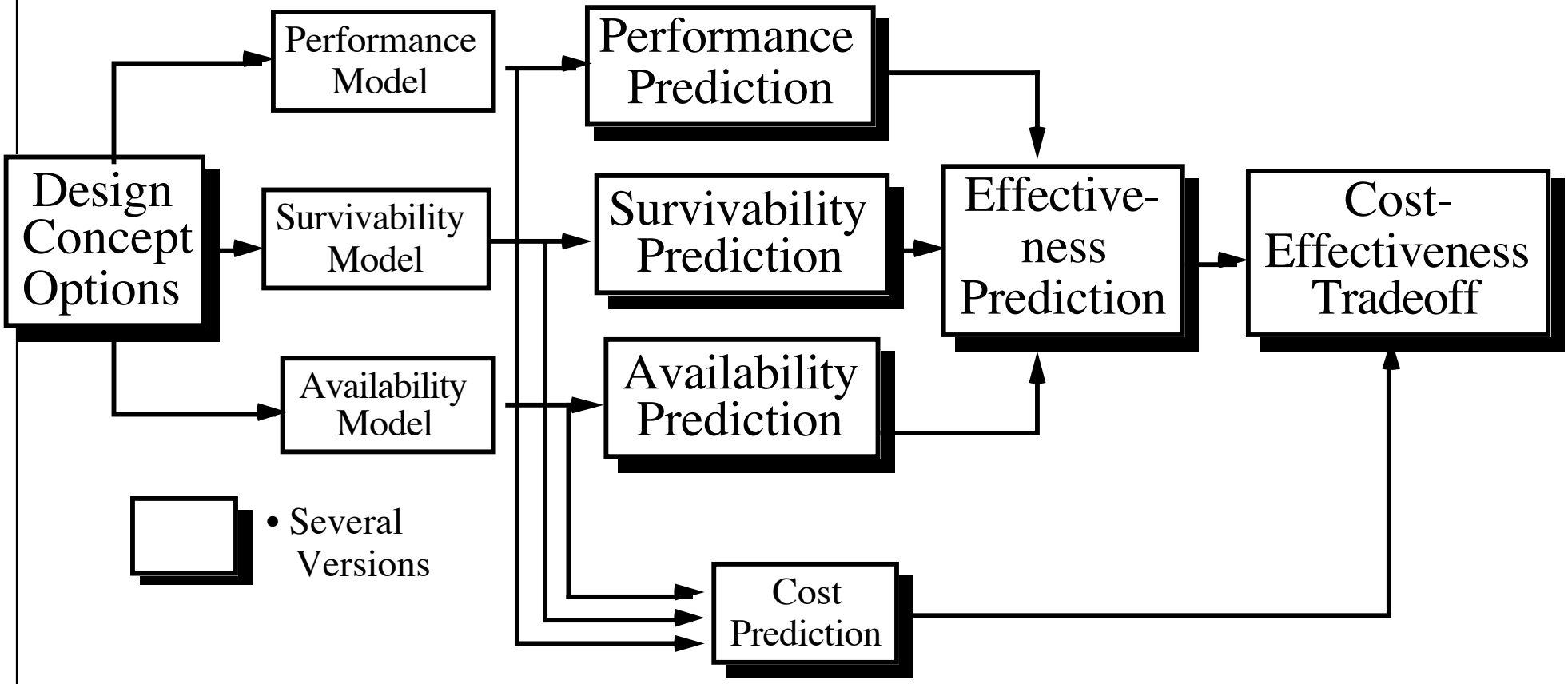
Effectiveness, almost by definition, accentuates the positive, but tends to play down the negative

By itself, effectiveness as a comparative measure can result in the most expensive item being chosen.

None-the-less, a great improvement over Efficiency

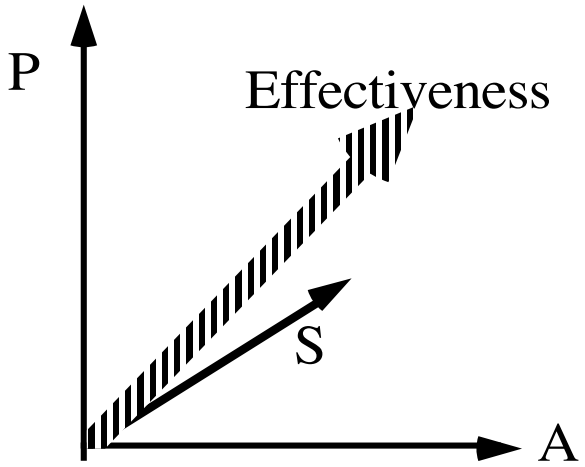
Cost-Effectiveness

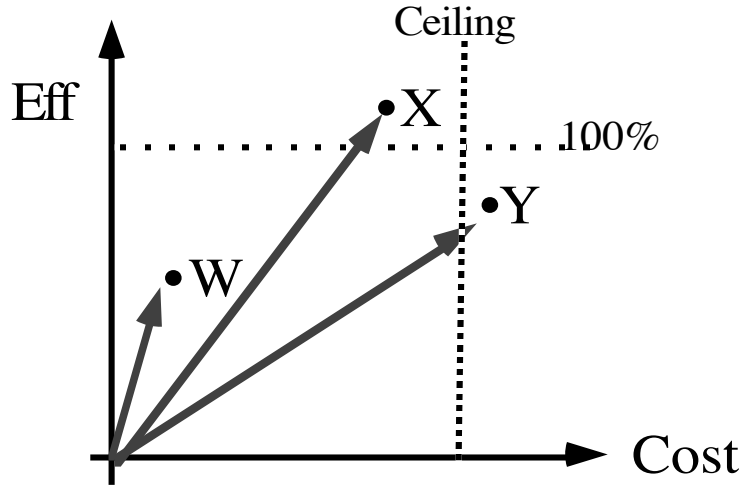
P. M'Pherson, City University



Manipulating Cost Effectiveness

$$\frac{\sum (\text{Performance} + \text{Availability} + \text{Survivability})}{\text{Cost}}$$





- Emergent Property Based
- Ratio Suspect—see •W
- Neglects Negative E.P.s
- Option-Range Dependent
- Comparative—Always gives an Answer, *even if none exists*

Cost-Effectiveness Question

A regional economy contains a number of large industrial organizations, each separately and independently developed to operate cost-effectively under the control of their effective BODs

Is the resulting economy necessarily well served by these organizations?

Is the regional environment similarly well-served?

If you believe so, justify your judgement

If not, what could be done realistically to improve the situation?

Net Contribution—1

Derek Hitchins

A systems approach, based on the fundamental concept that the only real value of a system is in its contribution to its Containing systems objectives. Gives absolute, as well as comparative, measures

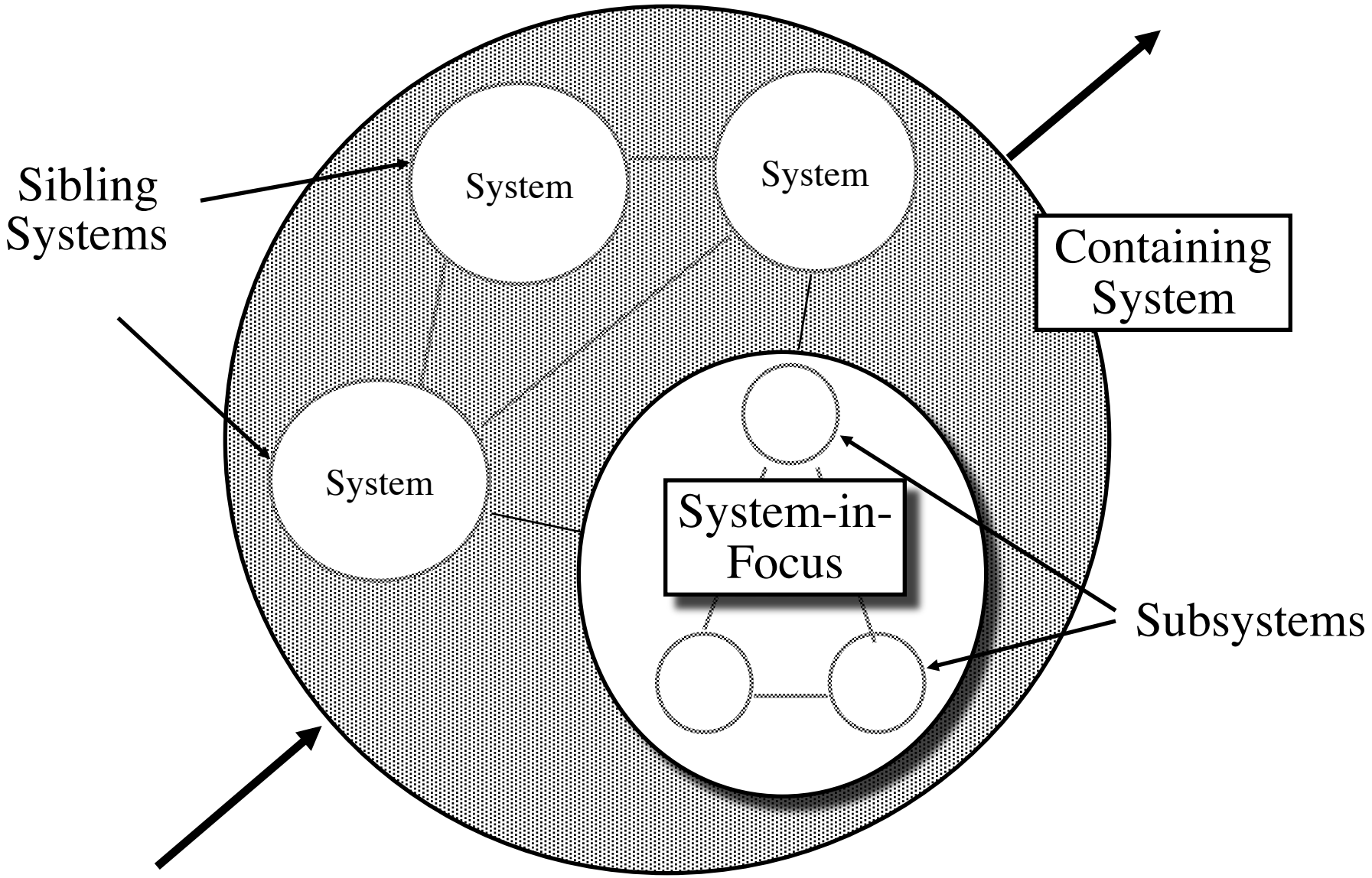
e.g. The only real value of a University is to its Education System's objectives; these can be seen best in the context of the next system up the hierarchy, in this case typically the National Economic System

The only real value of a gun is to its battery's objectives, seen best in the context of.....?

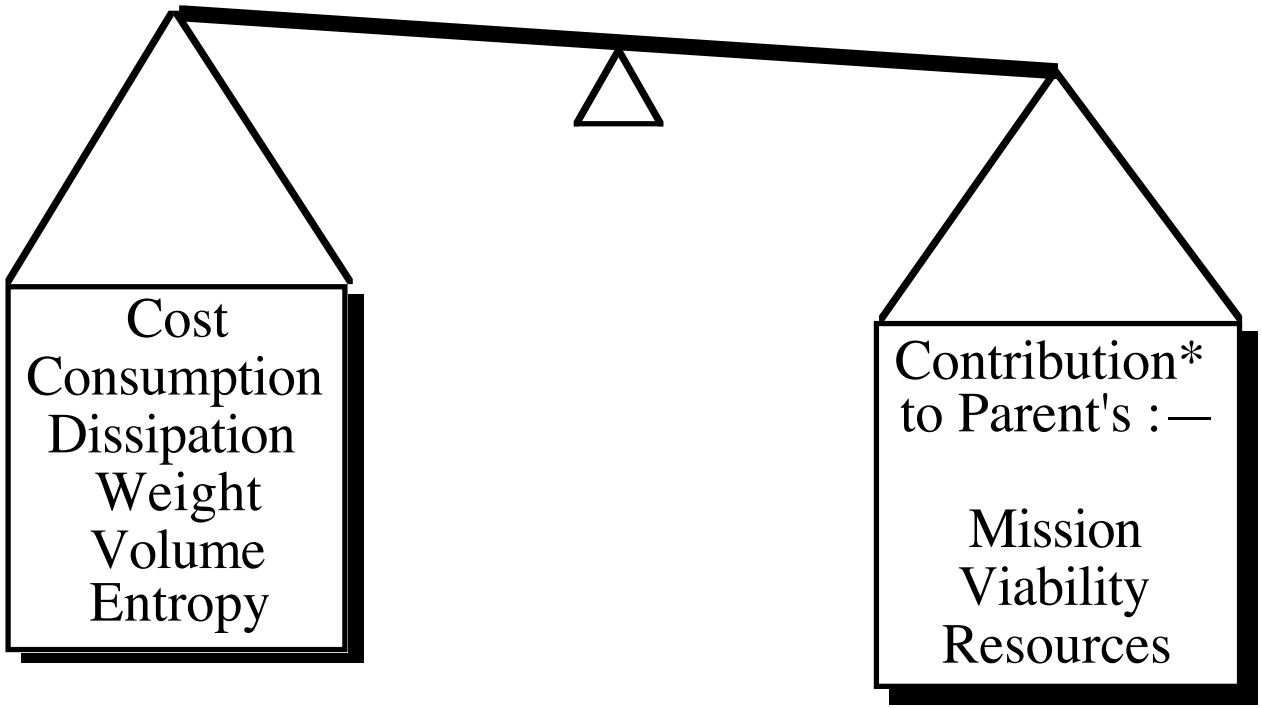
The only real value of a brigade is to its division's objectives, seen best in the context of.....?

The only real value of a divisional C2 system is to its division's objectives. These can see best in the context of the next system up the hierarchy, in this case typically the Corps.

System Hierarchies



The Contribution Balance

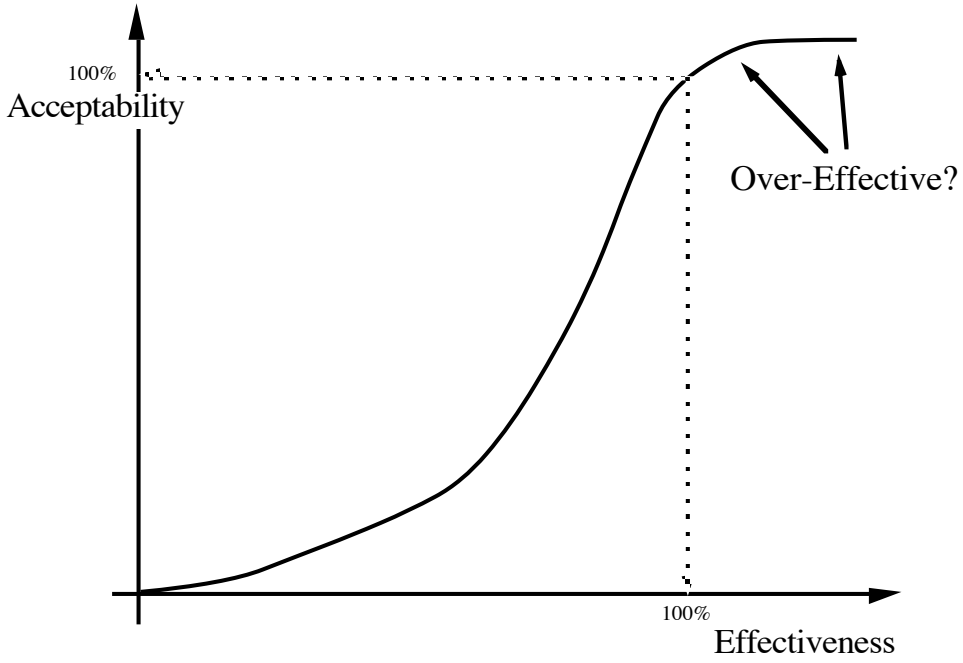


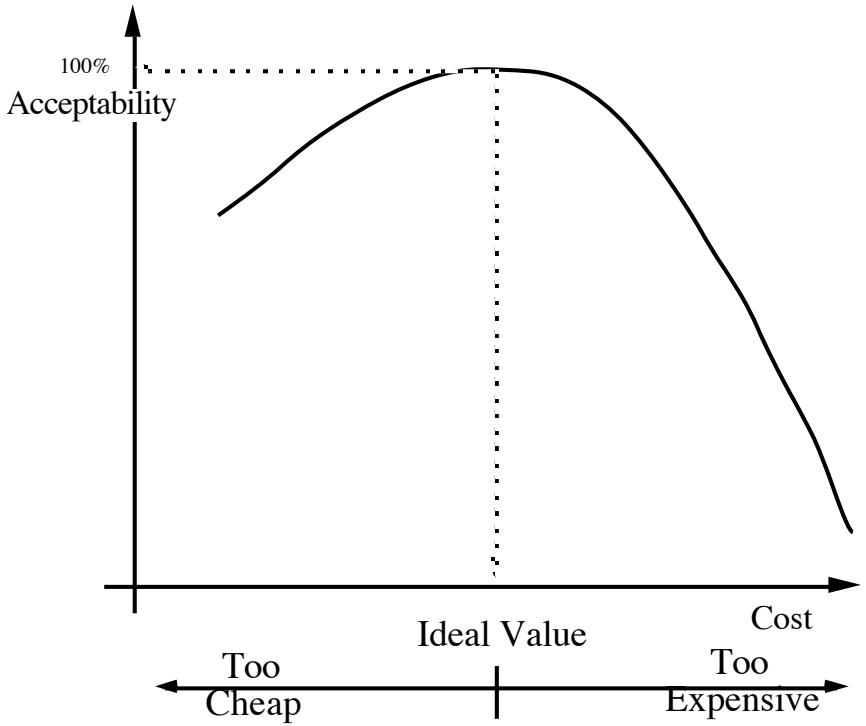
- Uses *All* Emergent Properties • Vector Algebra, not Ratioed
- Separates Positive from Negative Contribution—Clarity/Rigour
- Provides an *Absolute* Measure • Recursive—Any Hierarchy Level

* Complementary to Sibling Systems

*Parent = Container

Evaluating Positive and Negative Contributions





Positive Factors tend to the Logistic, or Sigmoid

Negative Factors tend to have a single peak

Net Contribution—2

A system may contribute net positively, or net negatively.

Where a system contributes net negatively, it may still contribute uniquely, such that the value of its positive contribution element is prized.

For this system to be acceptable, it sibling systems—which also contribute to the same Containing System objectives—must be able to compensate for the offending negative excess.

- **Step 1.** Evaluate the optional solutions for the System-in-Focus, judging shortfalls (or overruns) against the idealised emergent properties
- **Step 2.** Where shortfalls occur, seek to rebudget by trading with other Contained Systems

The Contribution Budget

Emergent Properties	Contained Systems									
Positive Contribution	A	B	C	D	E.	SIF.	N..	X	Y	Z
e.g. Performance										
Reliability										
Negative Contribution										
e.g. Size / Weight	2	3	4	2	7	5	3	1	2	1
Consumption										

Containing System Sums

30

Ideal Emergent Properties for each Contained System

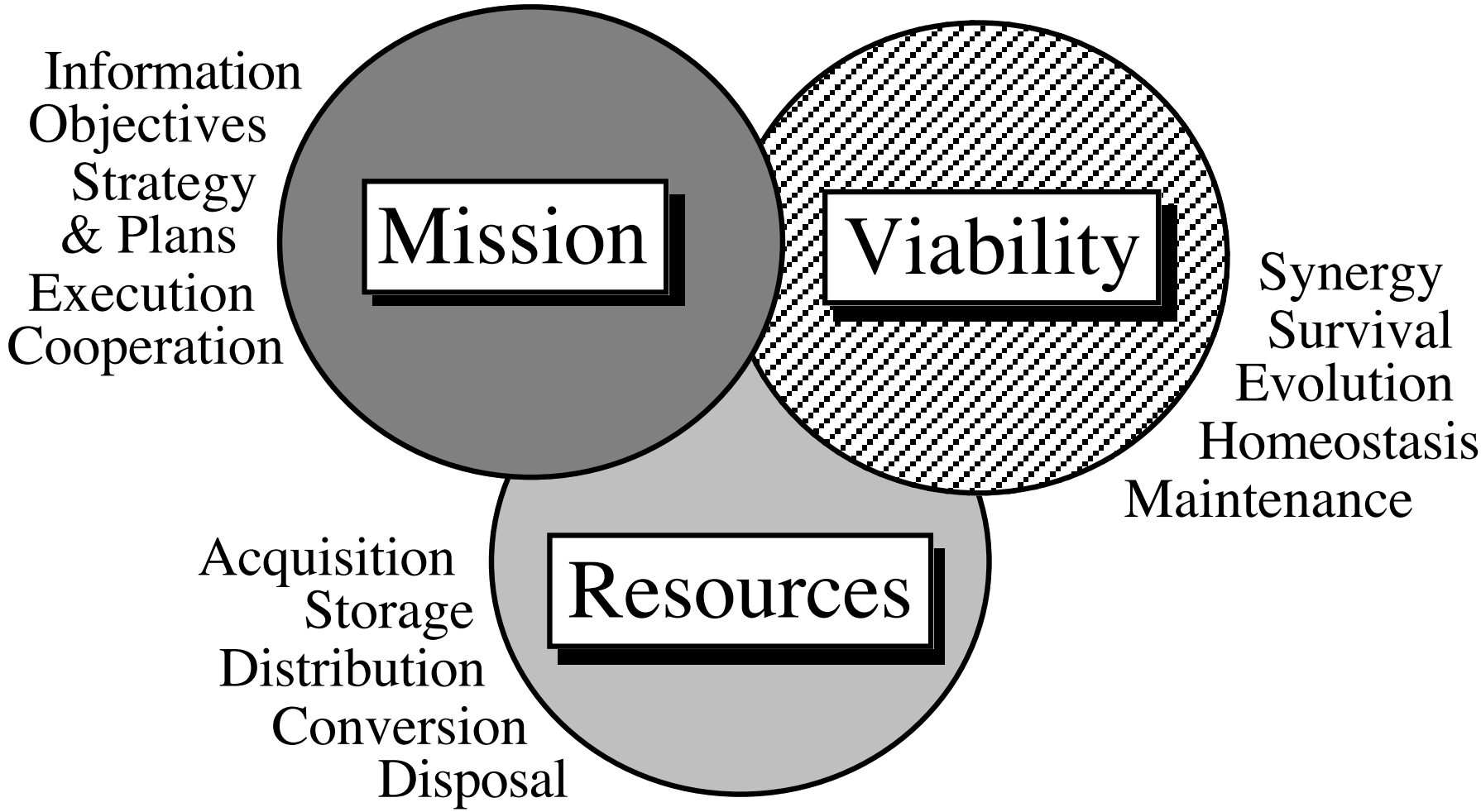
Options vs Budget

Emergent Properties *Positive Contribution*	Target Value	Optional Solutions			
		A	B	C	D
e.g. Performance	10	7	8	5	9
Availability	8	3	6	9	7
Survivability	5	5	5	6	4
Negative Contribution					
e.g.Cost	5	4	5	7	6
Size / Weight	10	6	11	10	12
Consumption	8	7	8	9	10

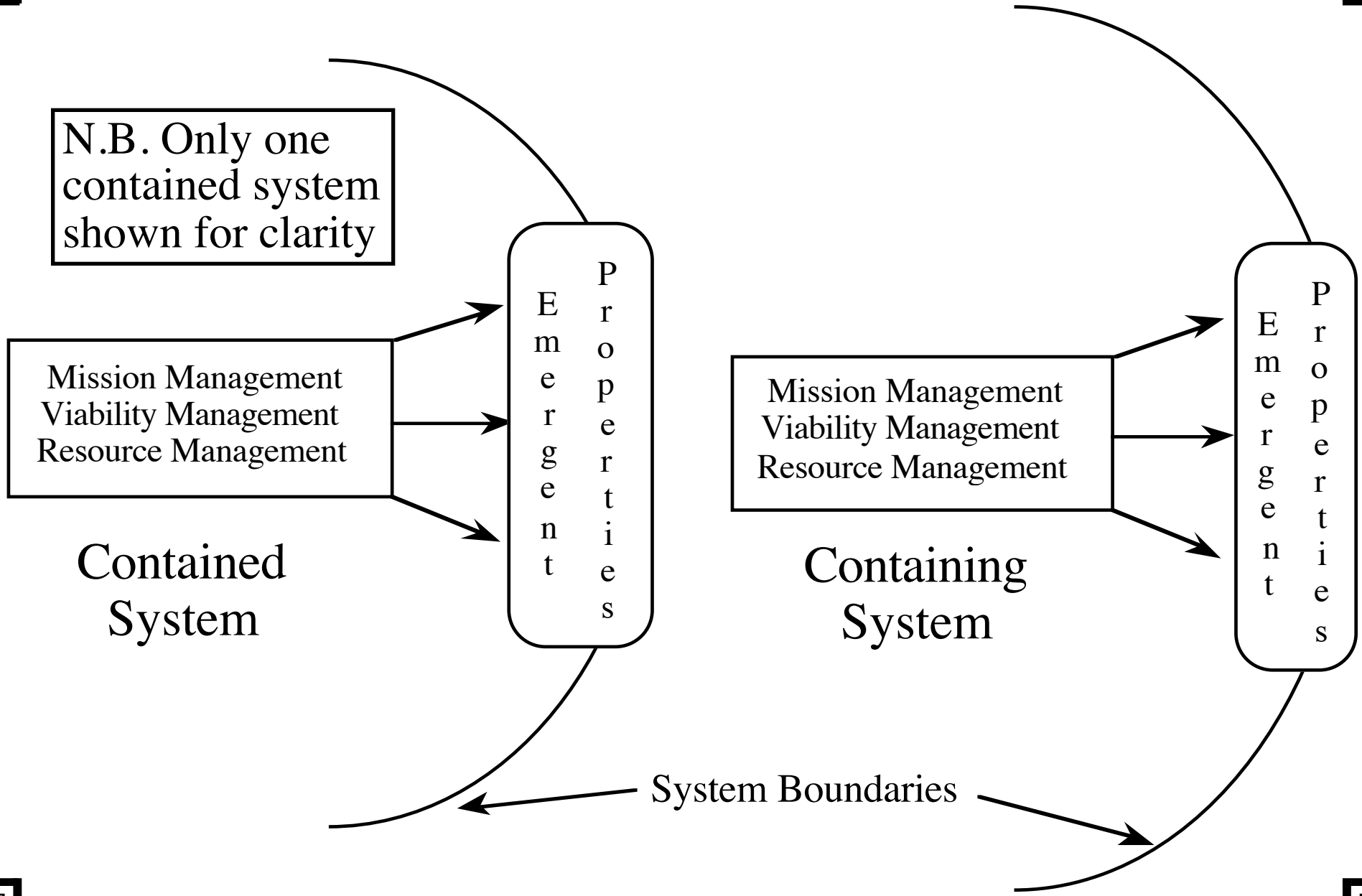
Best Performer is also over weight, over cost and over consumption.

Question: How much does it *matter*. Fechner's Law?

The Management Set



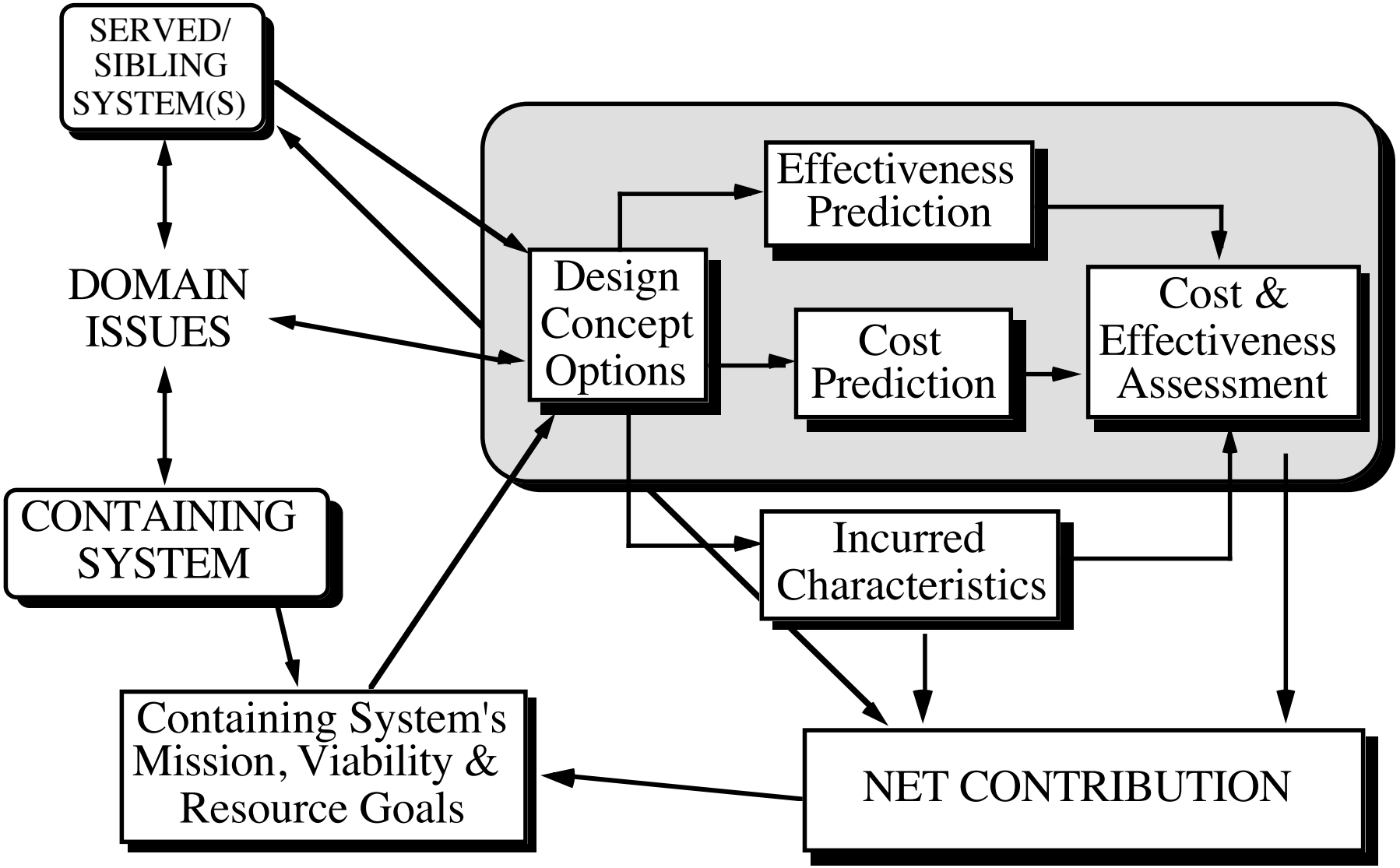
Internal and External Views of a System

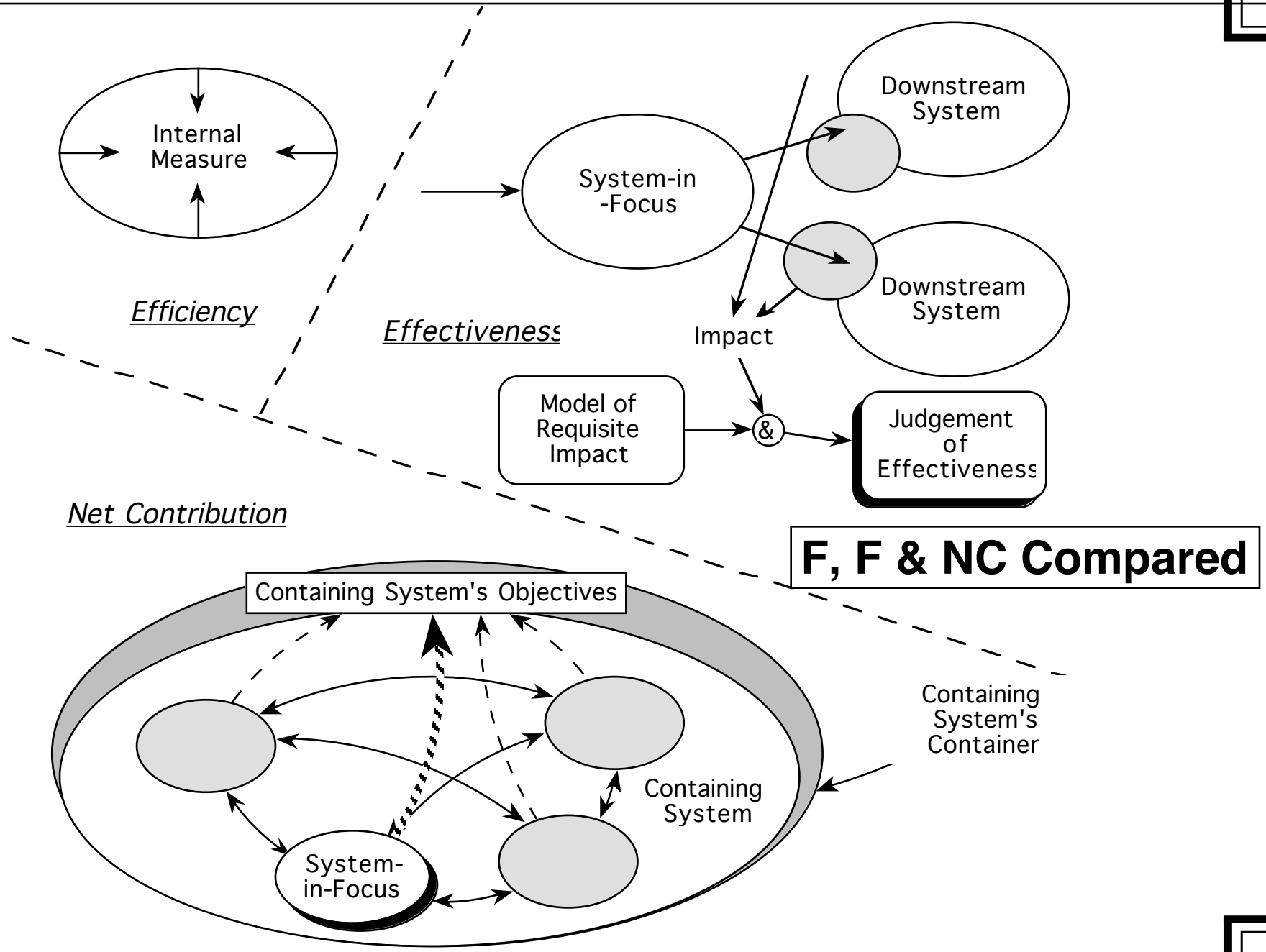


Net Contribution Matrix

SYSTEM-IN-FOCUS—EPS		CONTAINING SYSTEM														
		MISSION					VIABILITY					RESOURCES				
		Information	Objectives	Stgy & Plns	Execution	Cooperation	Synergy	Survival	Evolution	Homeostasis	Maintenance	Acquisition	Storage	Distribution	Conversion	Disposal
Performance	Container's Objectives															
	Sibling Interaction															
Availability of Performance	Reliability															
	Maintainability															
Interoperability	Communication															
	Protocol															
Usability	Human Factors															
	MMI / HCI															
Survivability of Performance	Avoidance of Detection															
	Self Defence															
	Damage Tolerance															
Security	Data															
	Physical															
Positive Contribution	Sum															
Cost	Capital															
	Ownership															
Energy / Power / Resources	Consumption															
	Dissipation															
Weight / Mass																
Volume / Shape																
Negative Contribution	Sum															
NET CONTRIBUTION	Sum *Difference*															

Cost-Effectiveness & Net Contribution



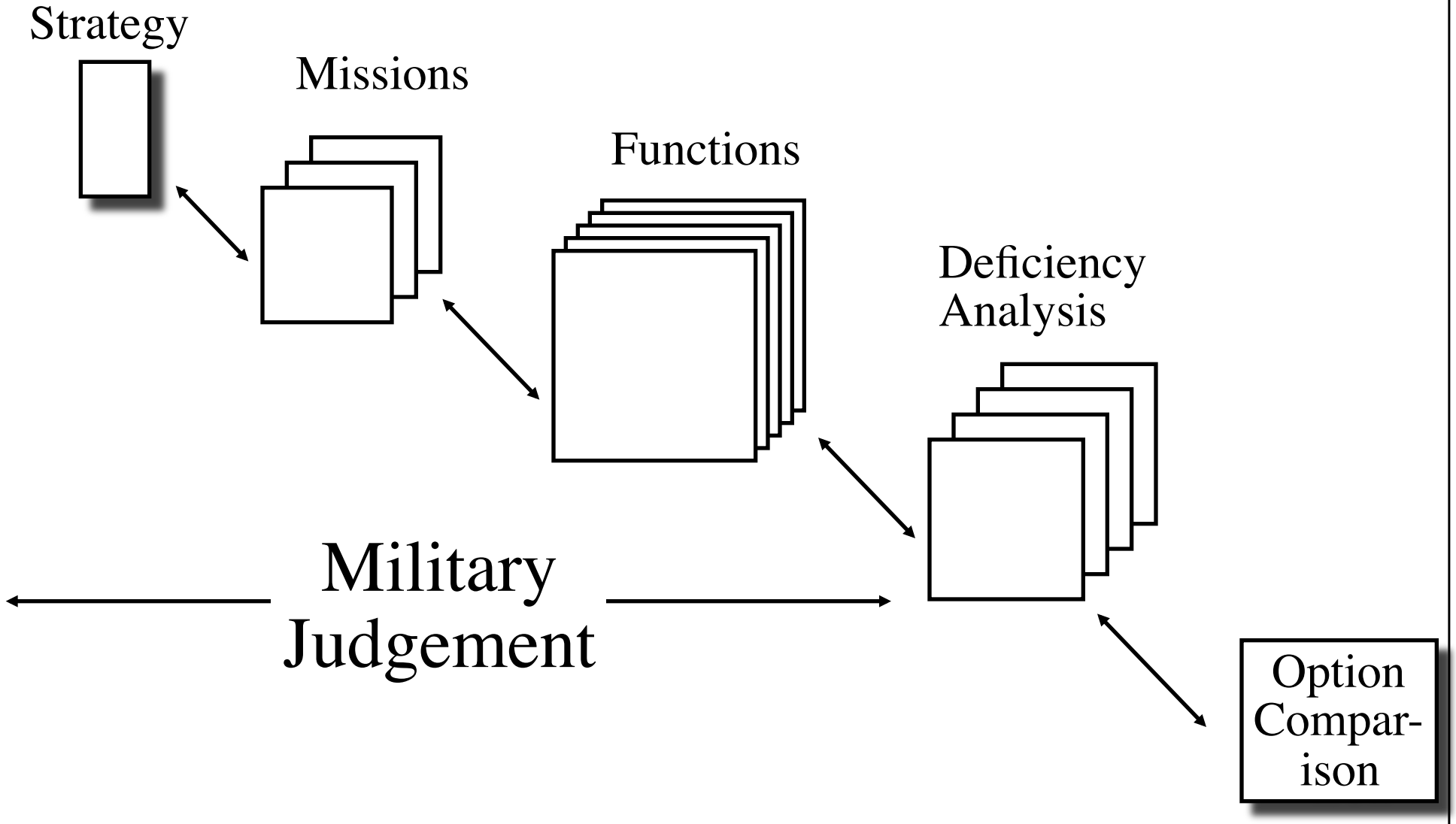

Internal Measure
System-in -Focus
Downstream System
Downstream System
Efficiency
Effectiveness
Impact
Model of Requisite Impact
&
Judgement of Effectiveness
Net Contribution
F, F & NC Compared
Containing System's Objectives
Containing System's Container
Containing System
System-in-Focus

BAe

- A Structured Method which Relates the Capability to Achieve an Objective to the Capability to Perform the Supporting tasks

cf Management by Objectives

MOA Methodology Matrices

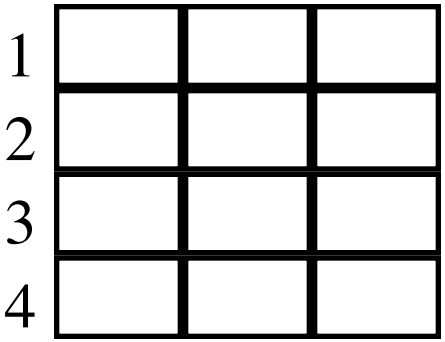


BAe, J R Murray, Head of Studies

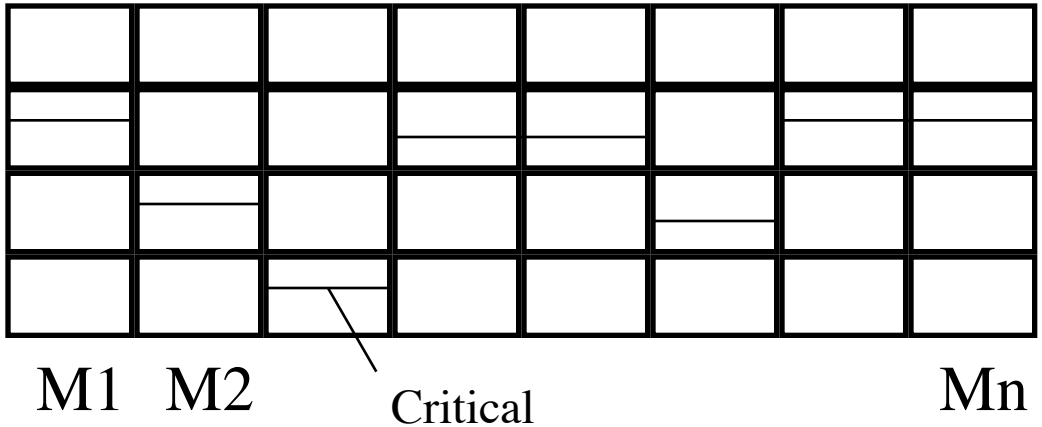
The Matrix Family

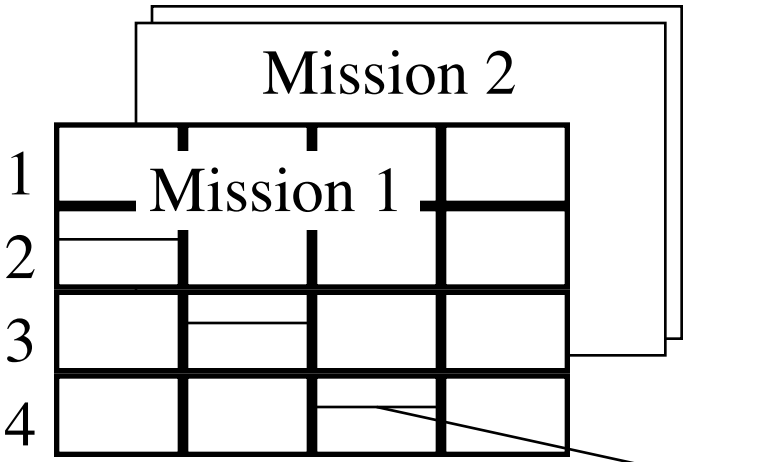
Strategic Capability

AVM Mallorie

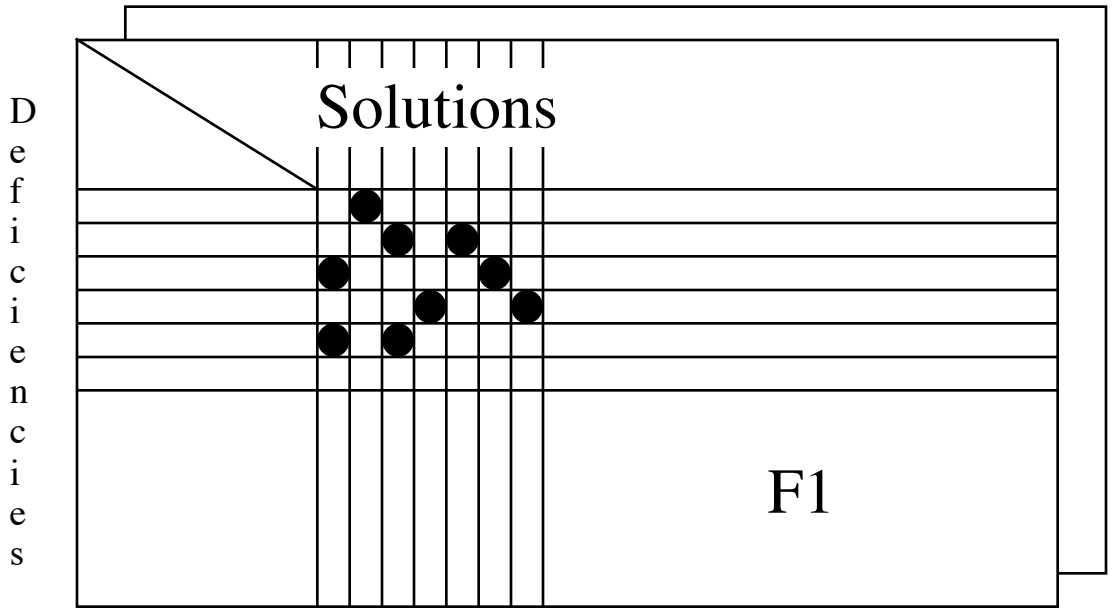


Mission Capability Matrix





Function Capability
—one per Mission



Function Deficiency Chart

MOA Product

BAe

- Identifies effects of capability deficiencies
- Suggests where effort gives best return
- Identifies critical points for anlaysis
- Provides common framework for examination of analyses, exercise and test results, war games and political and military judgements
- Provides a logic trail between military capability and political risk
- Suggests cost-aware step improvements

Conclusion

Efficiency is a poor, introspective, even dangerous, measure

Effectiveness is an external measure. Can give absolute and comparative evaluation. More complex than Efficiency

Cost-effectiveness ratios Effectiveness and Cost. Should enable more costly to be purchased if better value for money. In practice, used as a cover for cost-cutting

Net Contribution. More complex still, but getting to the heart. Only NC satisfies the original Components A—F of a Sound Project Evaluation Process

Mission-Oriented Analysis. What is the interaction between the Functions? How to choose between solutions? Interesting, but...