Trades in CAIV

TOC/CAIV Workshop 99-2

R. L. Coleman

ACQUISITION CENTER OF EXCELLENCE

Outline

- The requirement
- Trade rules
- Trade basics
- Risk in trades

Why *Do* Trade-offs?

- **Ordinary design requires tradeoffs**
- **CAIV requires tradeoffs to an unprecedented level**
  - Trades are the core of CAIV

How can trades be done effectively and quickly?

What are the issues?

Are there tools?

But first, to review the requirement ...

Principles of CAIV Within the DoN

- **CAIV embraces the following fundamental, iterative actions over the life cycle to optimize warfighting capability within affordability constraints and to promote program stability:**
  1. **Establish mission area resource allocations for each resource sponsor community.**
  2. **Determine operational requirements to meet mission needs.**
  3. **Estimate total life cycle costs to satisfy requirements.**
  4. **Project long-range availability of resources in all affected appropriations based on resource sponsor priorities.**
  5. **Assess cost, schedule and performance relationships.**
  6. **Establish aggressive target costs.**
  7. **Identify cost reduction opportunities and tradeoffs to meet aggressive targets.**
  8. **Develop plans, metrics and provisions for managing program execution.**

Principles of CAIV Within the DoN

- **CAIV employs a hierarchy of cost reduction activities, expanding the potential trade space. The recommended priority for cost reduction is:**

  (1) **Processes, activities and technology choices.**

  (2) **Requirements which do not directly contribute to warfighters needs.**

  (3) **Trade-offs that reduce cost while still meeting all operational requirements.**

  (4) **Cost-performance trade-offs of user requirements resulting in a breach of the approved operational requirement threshold are only to be accomplished as a last resort, with the agreement of the MDA and CNO/CMC.**

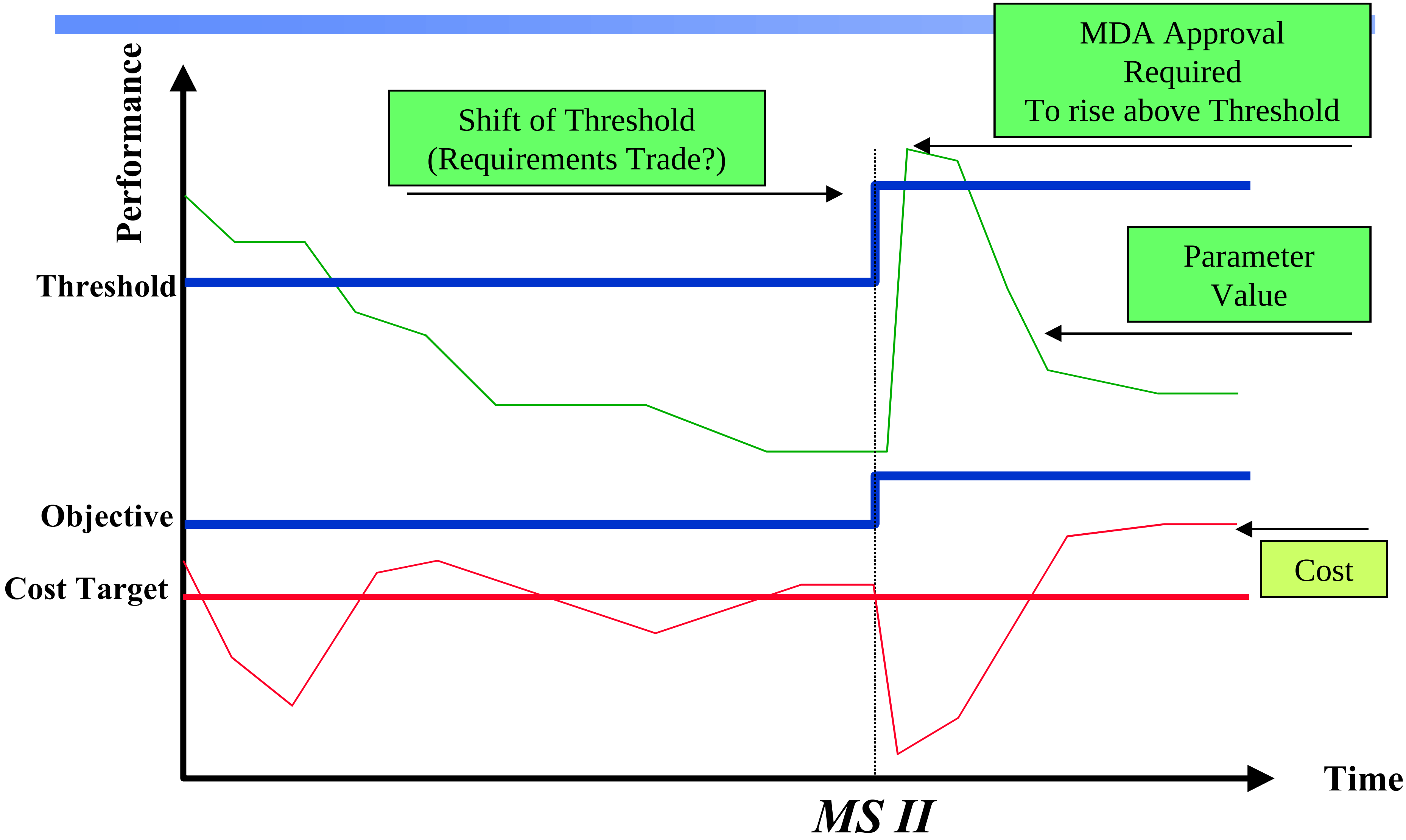
Rules for Trades

Trades - Boundaries and Timing

- **Trade bounds:**
  - **Trades between the Objective and Threshold values are within the purview of the PM.**
  - **Outside these values, they are the purview of the MDA -** ***DoD 5000.2 Ch-3***
- **Trade timing**
  - **P*reparatory* to a Milestone: Requirement/Cost trades**
    - **By the Gov t with industry participation**
  - ***During* a phase: Cost/Performance trades**
    - **By the Prime with PM participation**
  - **These two trade types are similar in conduct, but can be thought of as first and second steps**

ACQUISITION CENTER OF EXCELLENCE

Performance and Thresholds



Trade Basics

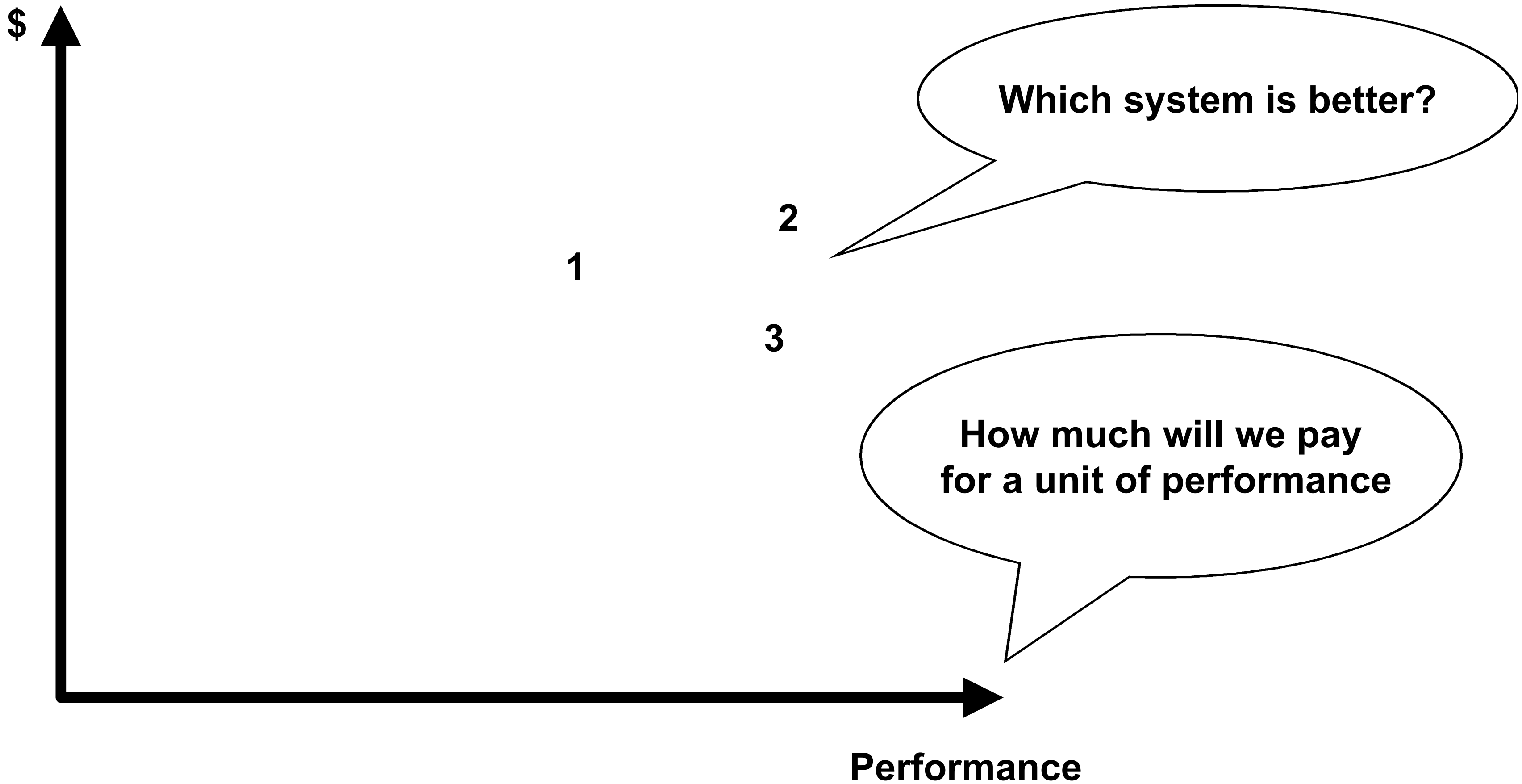
Cost/Performance Trade Challenges

- To trade cost and performance, the two must be compared in some common unit (co-mensurable)
  - This is often impossible in military applications and is even hard in business value is notoriously difficult to determine
  - This problem is a classical issue in Operations Research
- As in the conduct of COEAs and AoAs, the practice often is:
  - To compare alternatives with one or the other fixed
  - To adjust one or the other variable to match in all of the alternatives
- Sometimes the comparison is simple, involving strict dominance (e.g., better performance, less cost)
- There are a few basic methods
- But, In difficult cases, military judgment may be necessary
  - *Less taste ... more filling*

Cost/Performance Trade Challenges

- Linkage - To trade, you must be able to show cost for each alternative
  - Some alternatives are hard to cost out
  - Costs don t change if CER input variables don t include the parameter you changed
  - Even if possible, the volume and speed of trades can make linkage hard
- Exchange rate - To trade, you must know the dollar value of performance
  - What is one knot of speed worth?
  - What is the dollar value of greater accuracy

Linkage and Exchange Rate

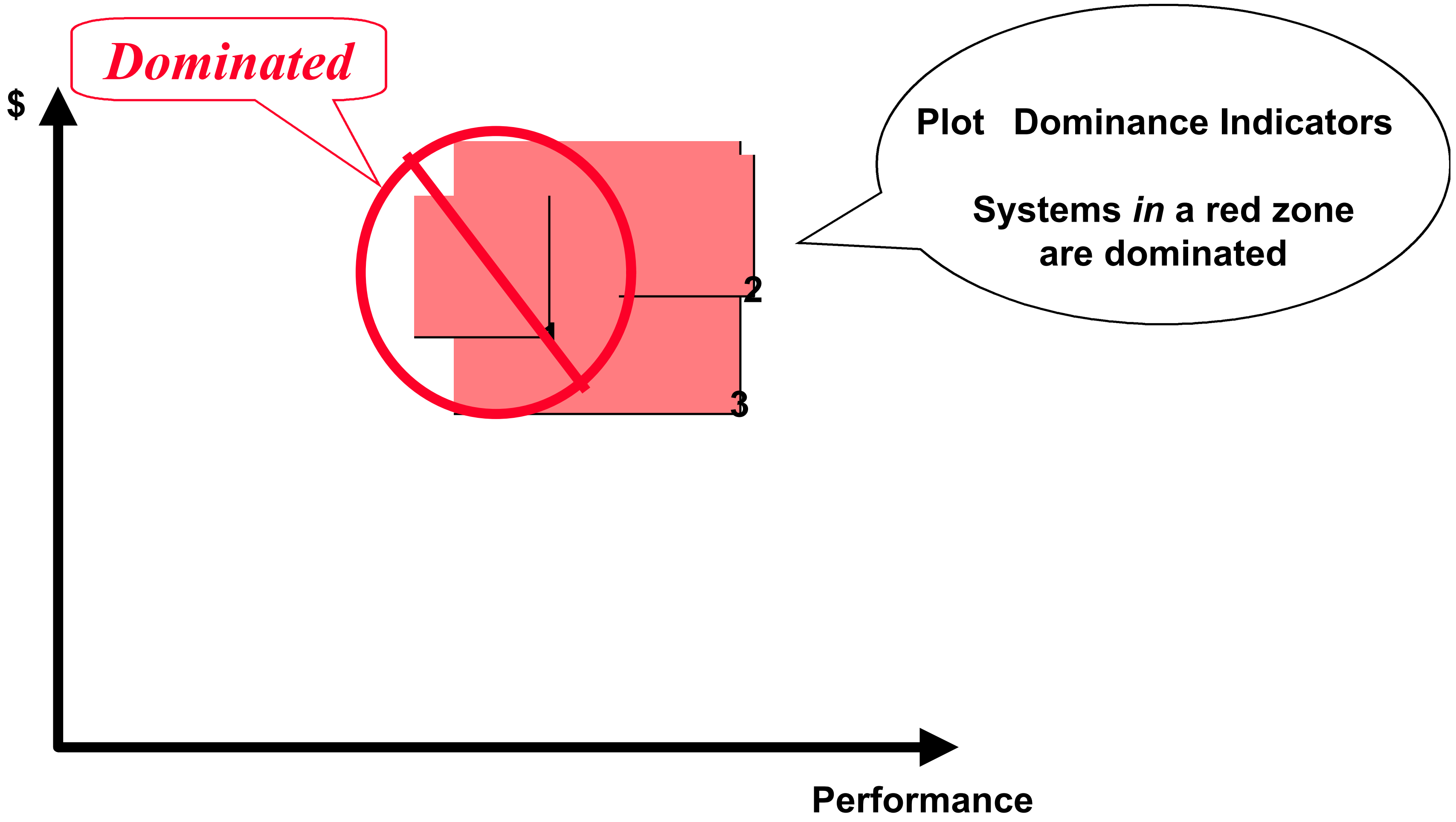


Linkage lets you plot the points
Exchange rates let you choose

Two Basic Methods of Trading

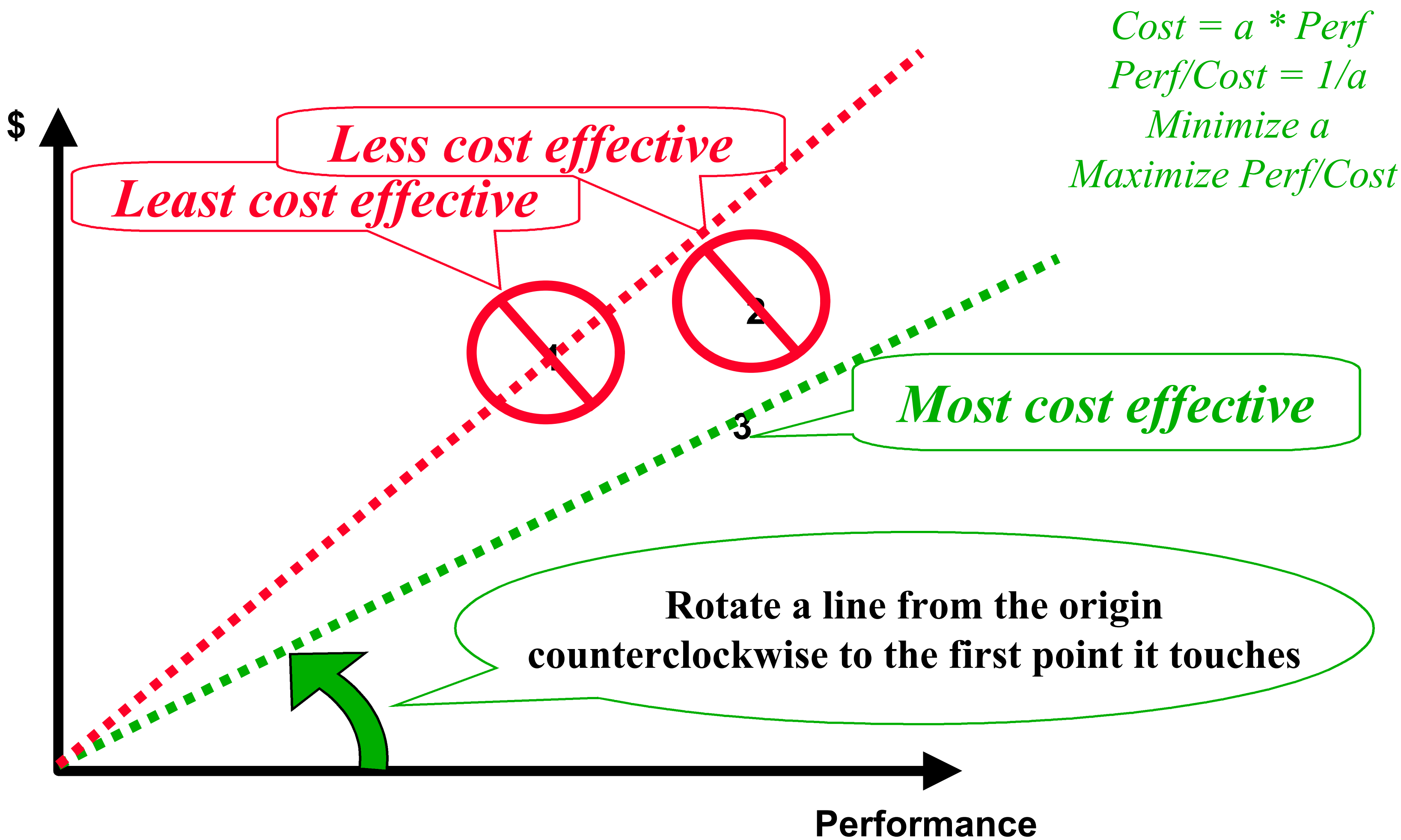
Without establishing the cost/value relationship

Strict Dominance Without Co-Mensurability

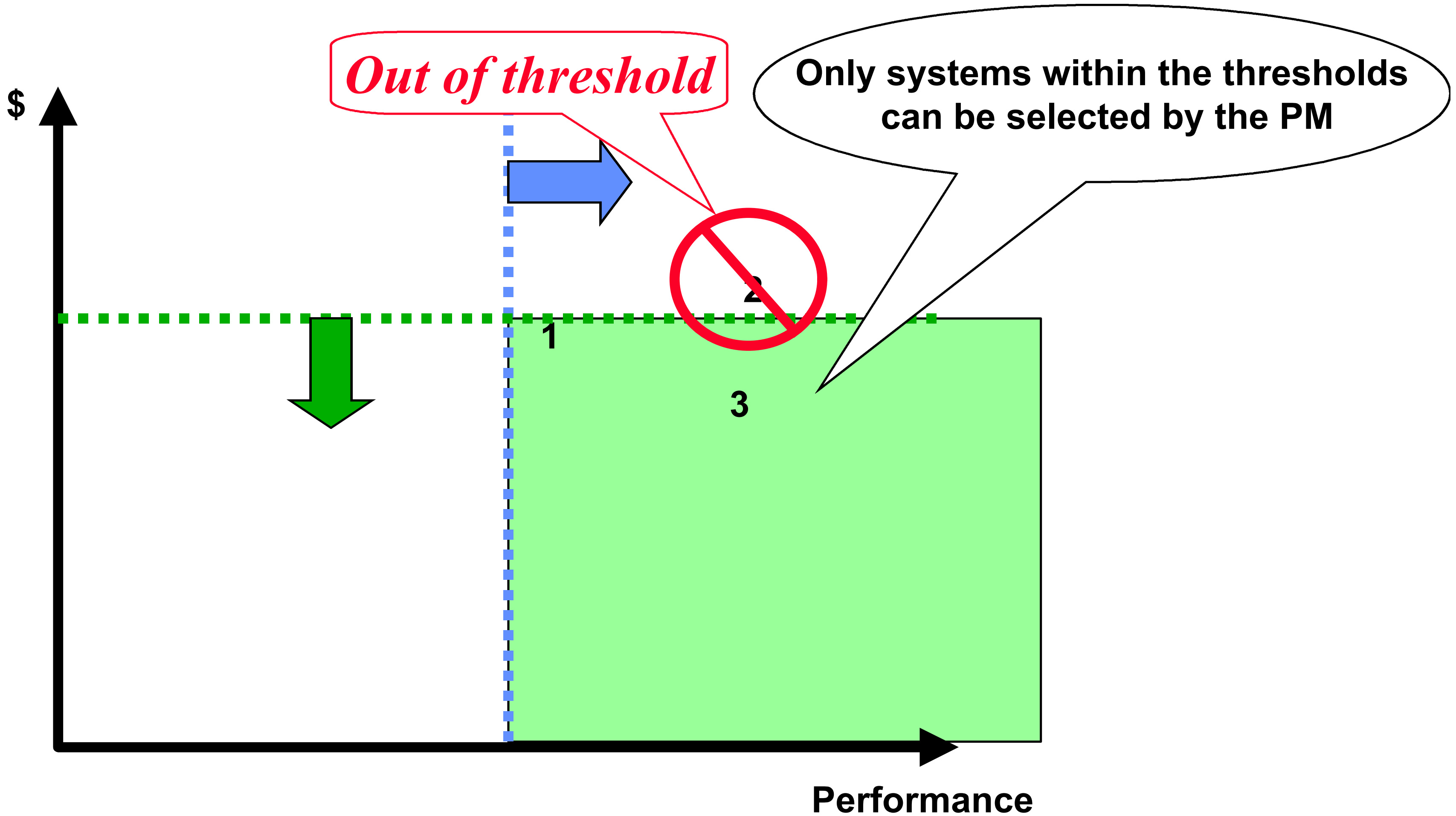


Best Bang for the Buck

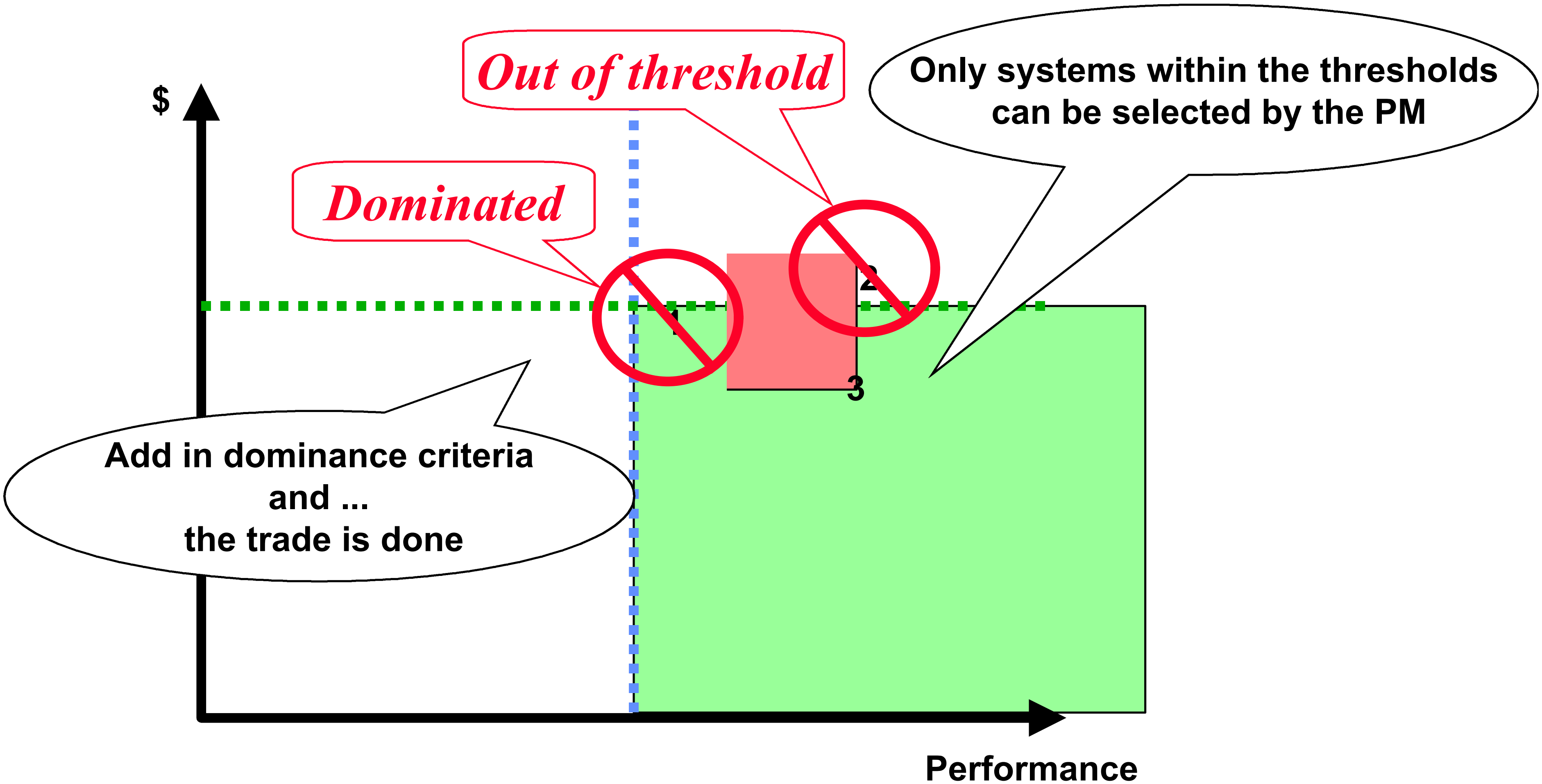
When Cost is Very Important



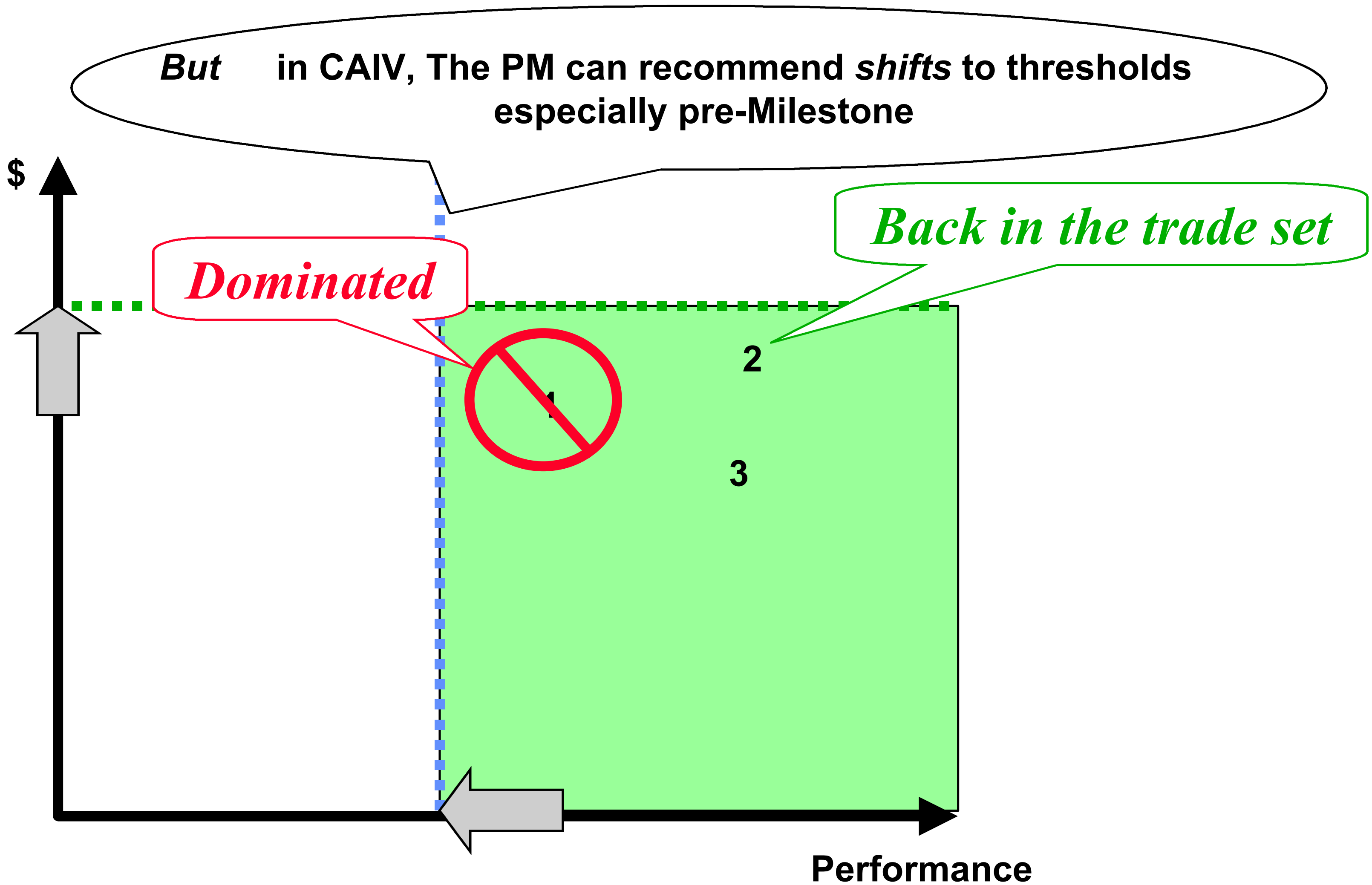
Choosing Within Constraints



Choosing Within Constraints

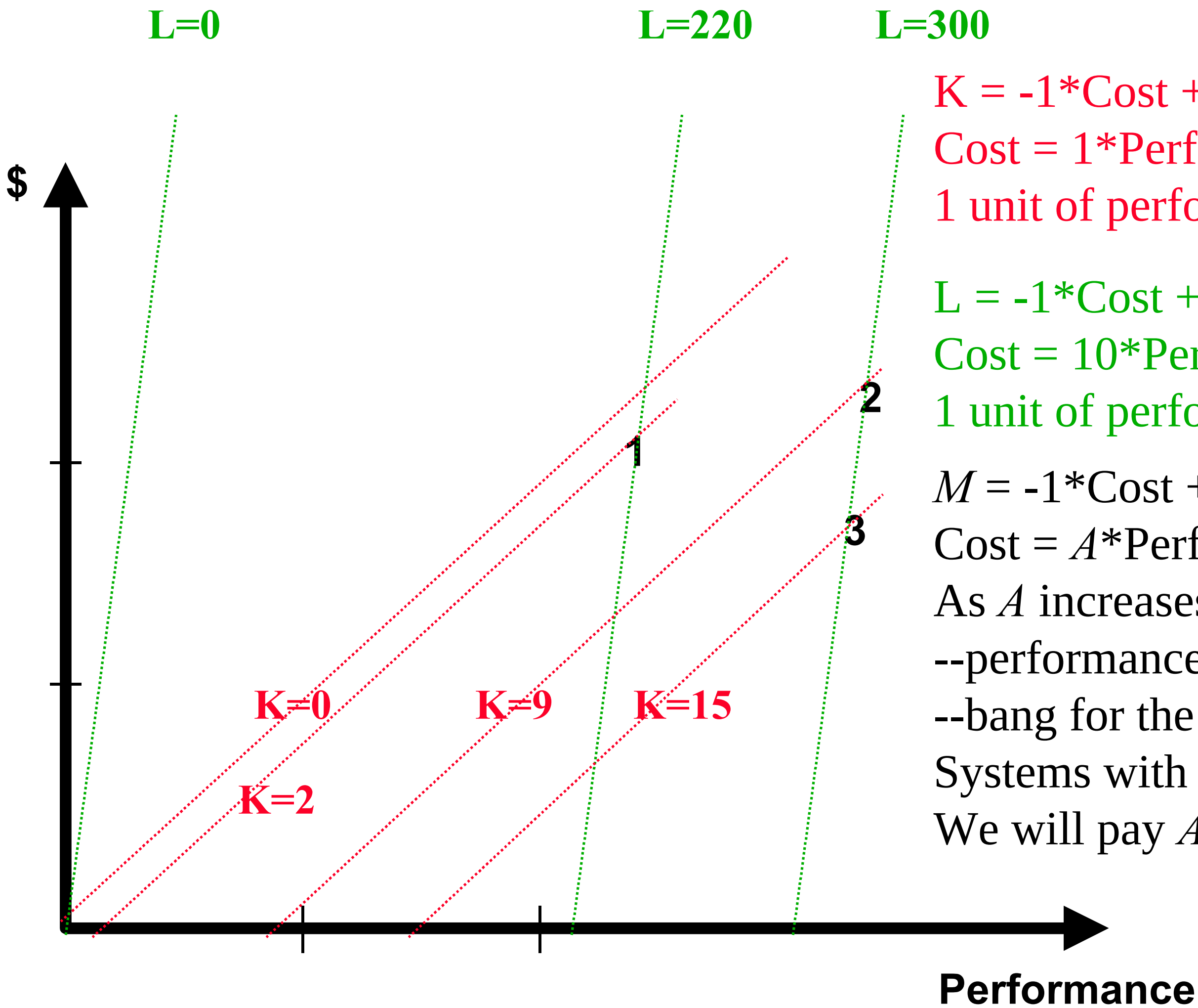


Choosing Within Constraints - Caveat



Exchange Rate

When you know the Dollar Value of Performance



K = -1*Cost +1*Perf
Cost = 1*Perf - K
1 unit of performance = 1 unit of cost

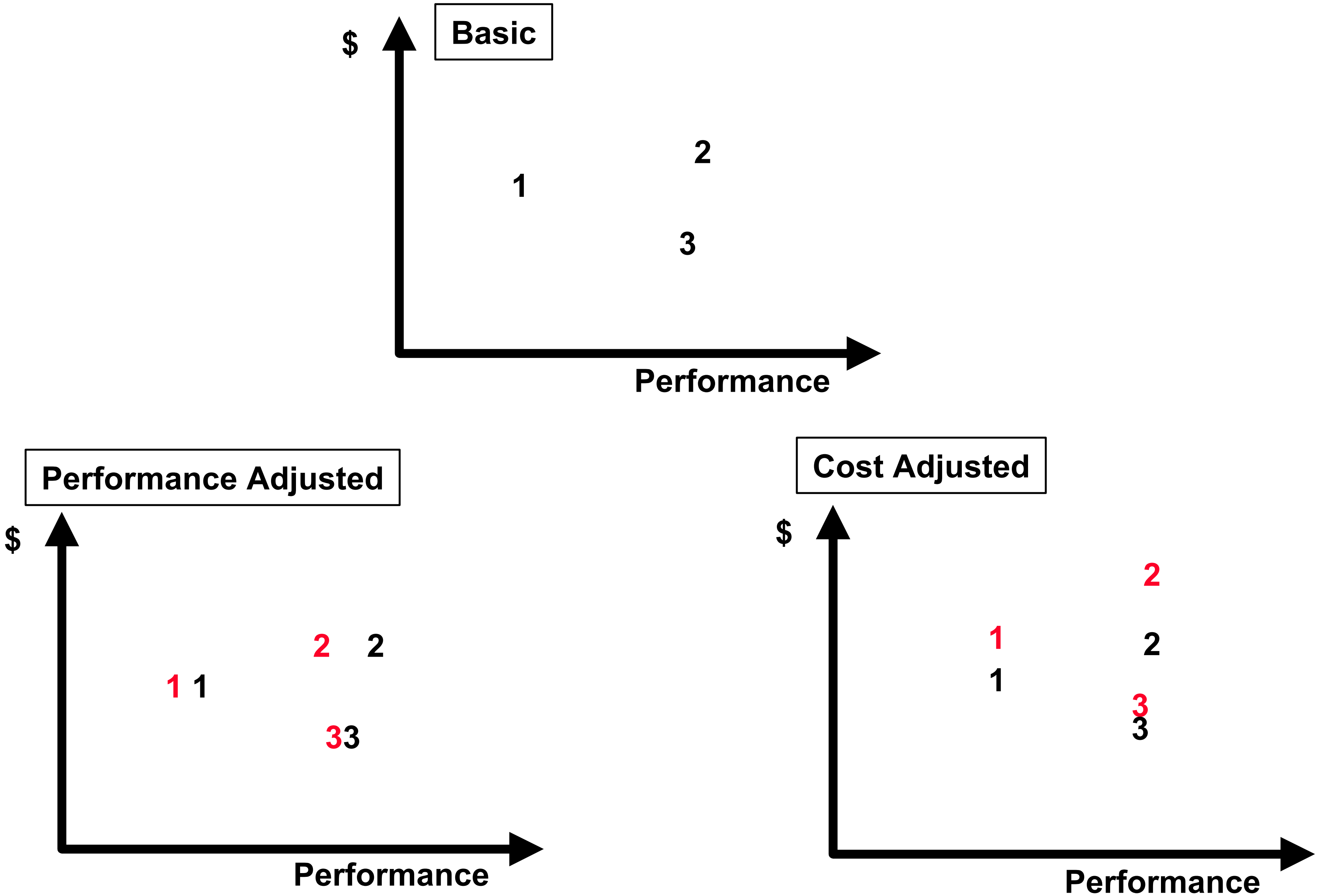
L = -1*Cost +10*Perf
Cost = 10*Perf - K
1 unit of performance = 10 units of cost

M = -1*Cost +*A**Perf
Cost = *A**Perf - *M*
As *A* increases,
--performance is more important,
--bang for the buck is sacrificed
Systems with higher *M* values are preferred
We will pay *A* dollars per unit of performance

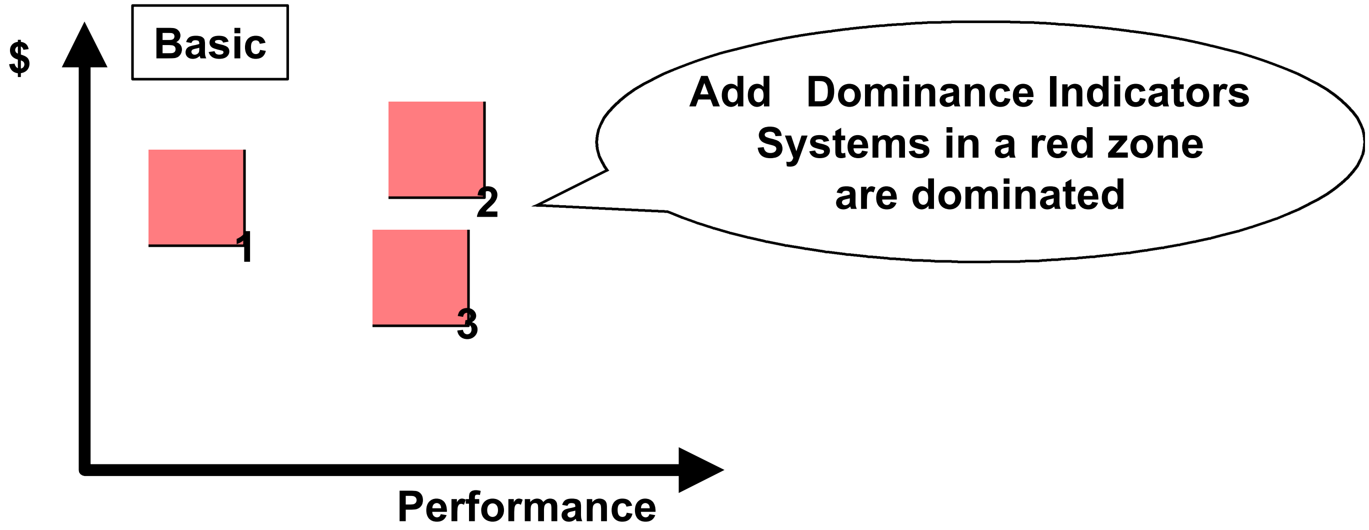
Risk in Trades

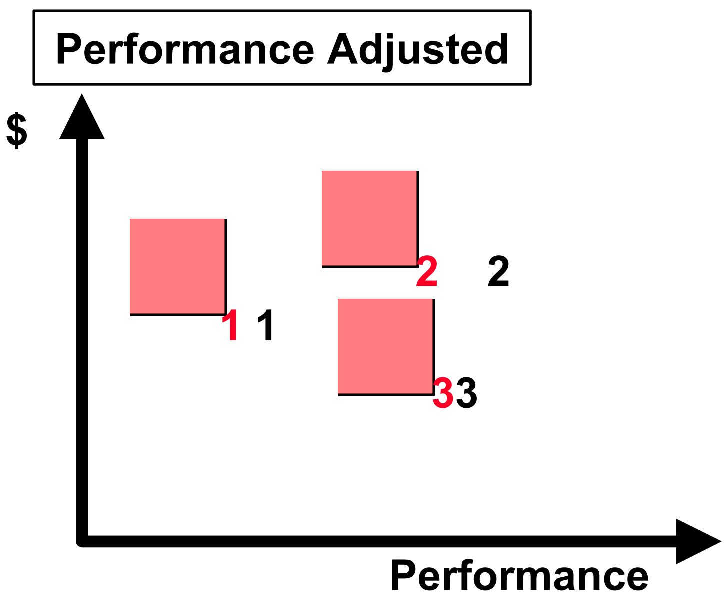
- Risk is a fact of life, and is higher in TOC and CAIV.
  - How should it be handled in trades?
- In life, we see risks as separate, discrete outcomes:
  - A car crash
  - A disease
- In cost, and Program Management, risk is *a failure to achieve a goal* ... an *un-anticipated value of a metric* we are managing:
  - Cost over-run
  - Performance shortcoming
  - Schedule slip
- To handle this sort of risk, adjust the expected value of the metric
  - This is simple in concept, and well established in practice
- This simplifies our problem:
  - Reduces the number of potential variables by one
  - Avoids the issue of non-comensurability which arises in trading risks and dollars
    - A problem already hard enough in cost and performance trades

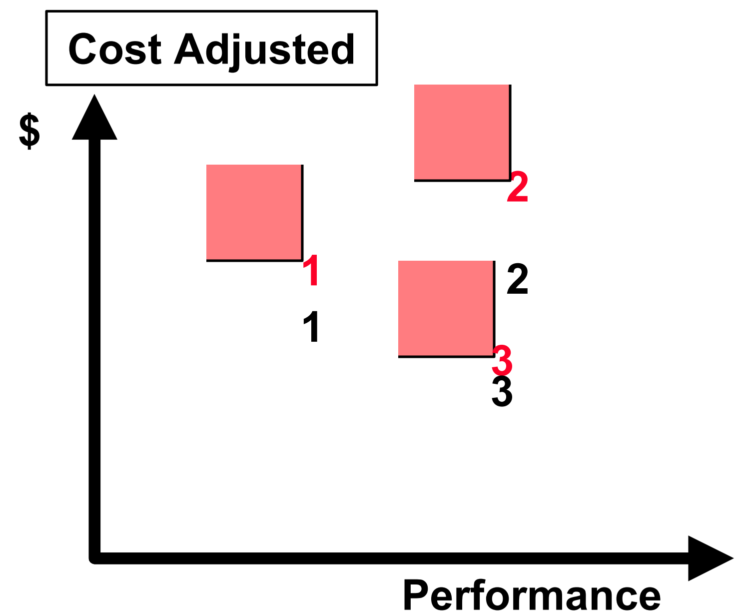
Risk Adjustment Illustration



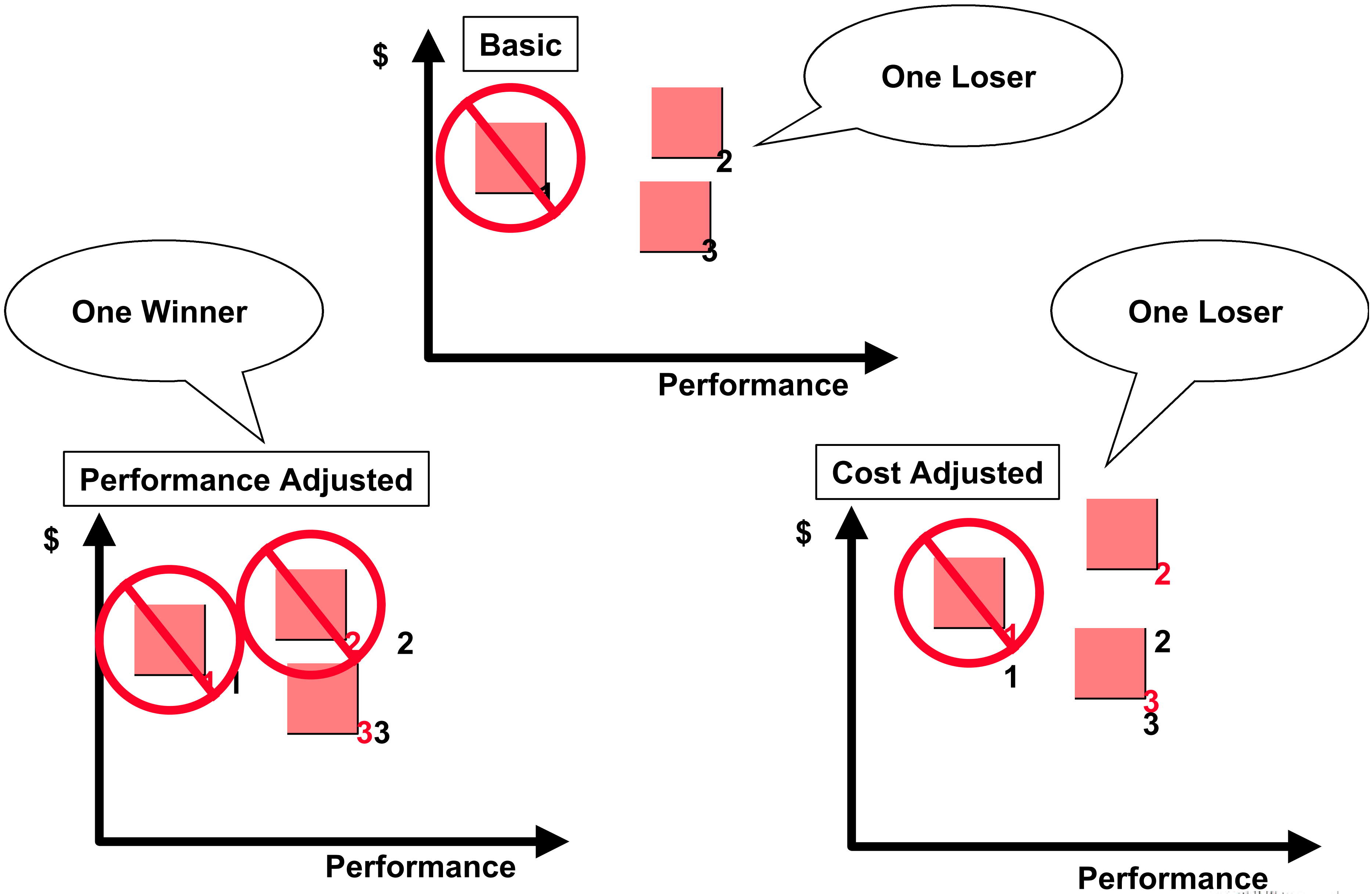
Risk Adjustment Illustration







Risk Adjustment Illustration



Backup

Design Sheet
by
BOEING

Caveat

- Design Sheet contains no equations
  - It is an equation solver
  - You must give it the equations
  - But, if you don t have equations, you can t do trades
  - If you do have equations, Design Sheet will help you do trades much faster

Description

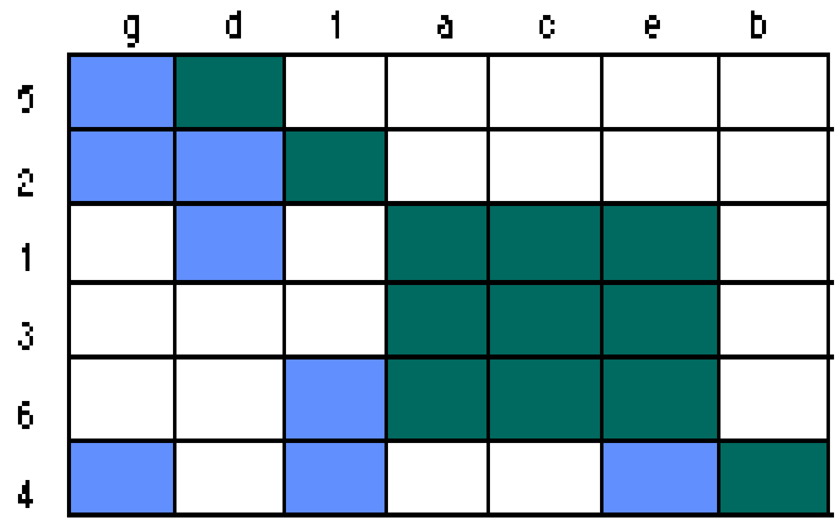
- DS is a software implementation of a constraint management methodology which facilitates tradeoff studies during conceptual design
- This methodology decomposes large constraint networks into smaller pieces that can be solved robustly, and can solve extremely large systems of non-linear equations present in practical system models
- DS allows the designer to:
  - interactively develop models, flexibly define tradeoff studies
  - quickly explore large areas of design space
- DS has been used on practical applications bounded by
  - system-level design of spacecraft using combined performance and cost models
  - design of a Navy quarter-scale submarine (LSV II)
  - preliminary design of automotive bearings

Converting Constraints into Ordered Equations

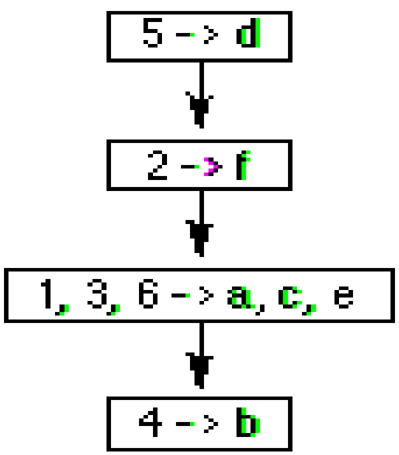
Design Sheet takes a series of equations

1. $a^2 + \log(c) = d$
2. $d \sin(f) + g = 0$
3. $a - c = e^2$
4. $b = e + f$
5. $d^2 + 5dg = 6$
6. $ac = e - f$

The equations are put in a graphic table,

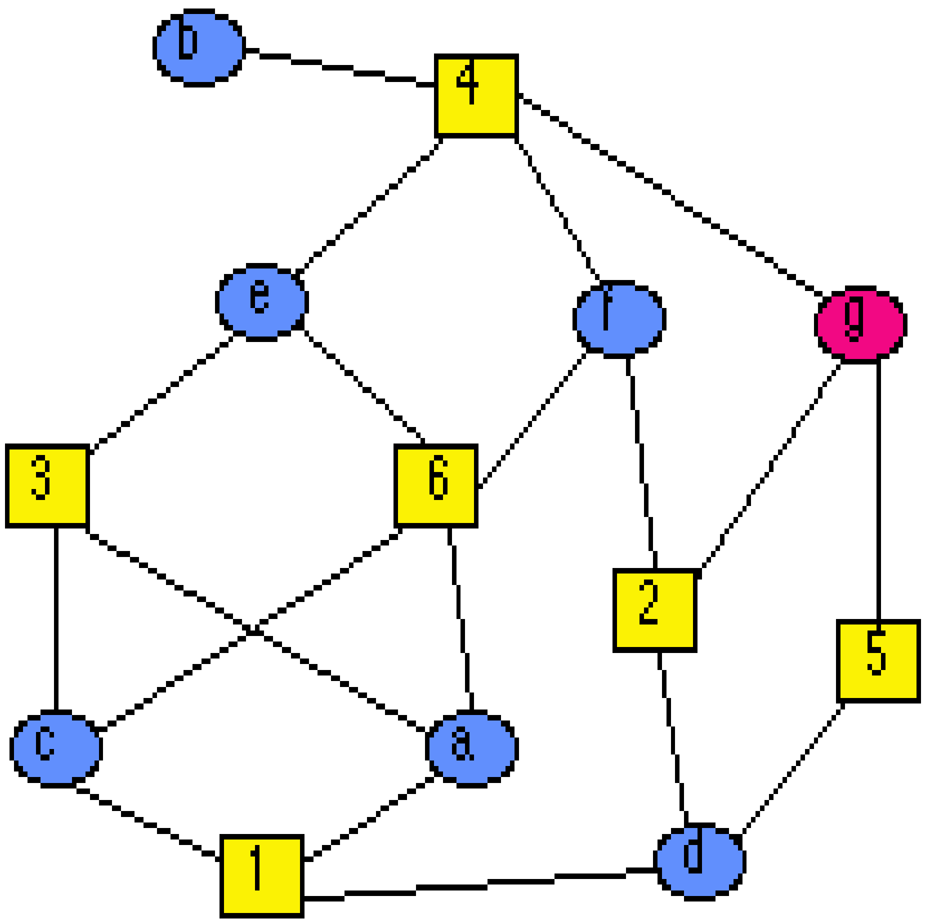


Partially ordered equations are created,



Constructing a Bipartite Graph

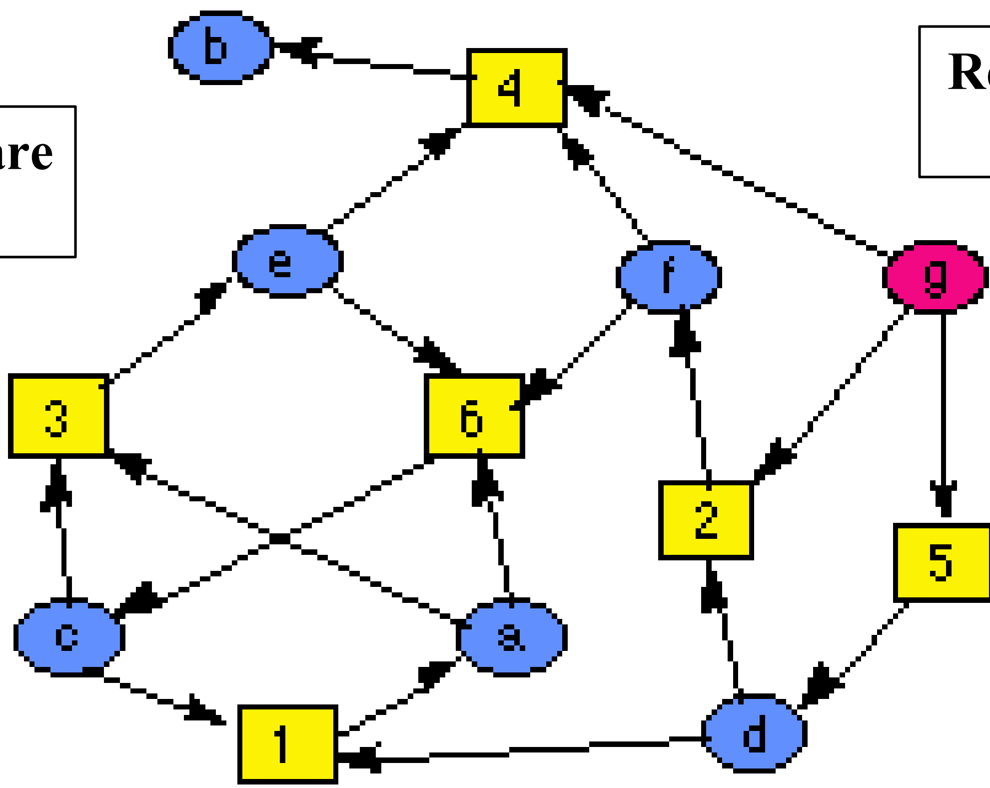
A bipartite graph is constructed, in which all variables (letters) that are in equations (numbers) are shown with connecting lines



The Directed Bipartite Graph

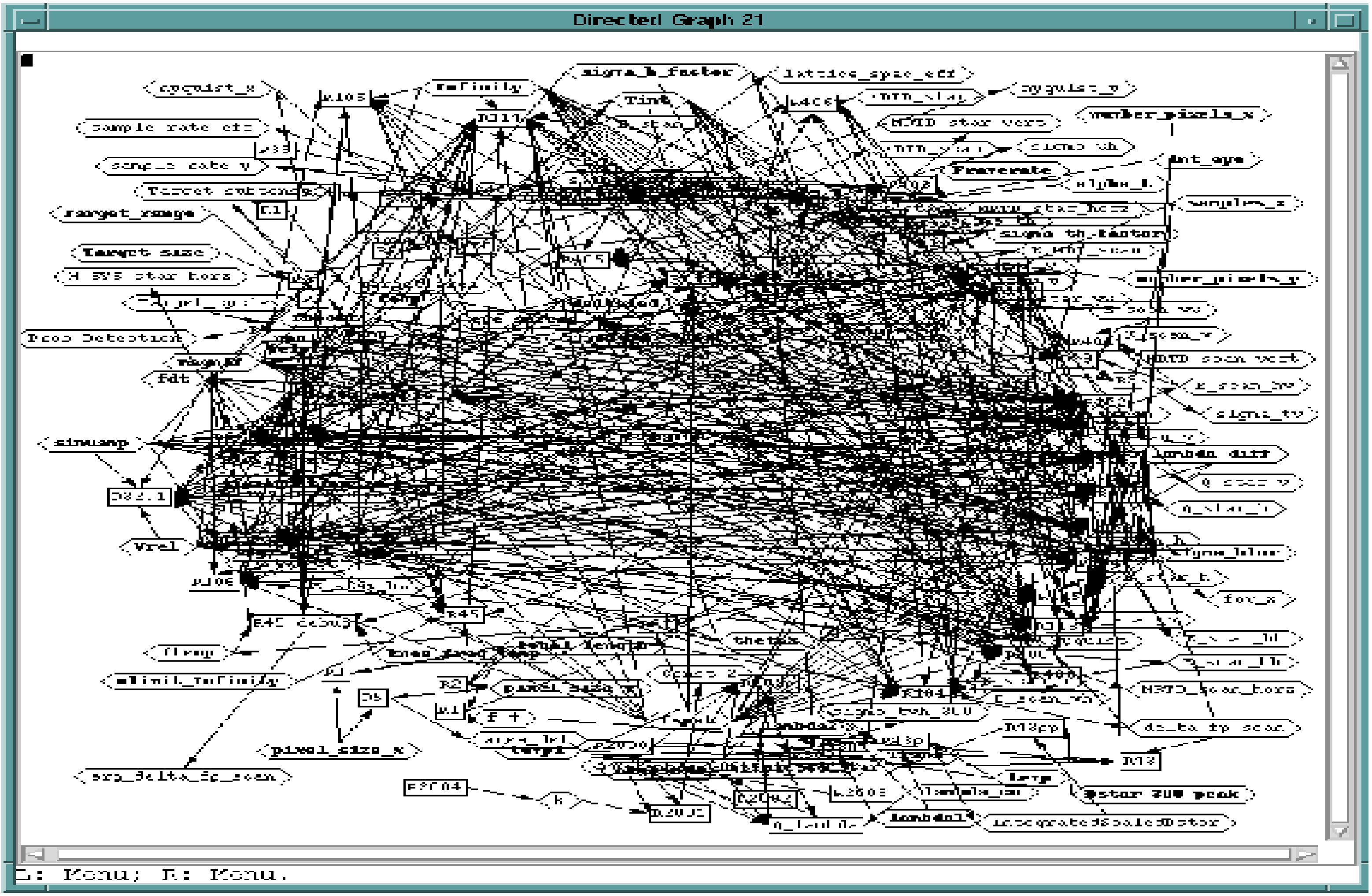
A directed bipartite graph is then constructed, in which the connecting arrows show causation in the functional sense, with equations ordered as determined by the ordering step

Blue Variables are Dependent



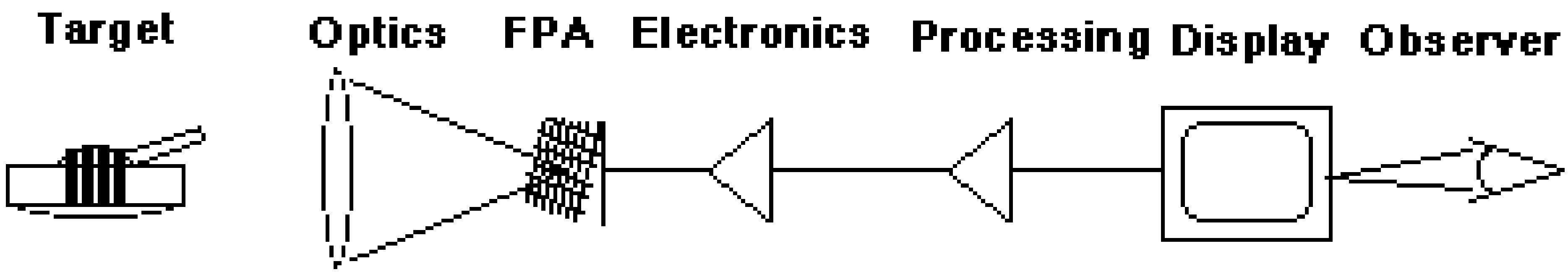
Red Variables are Independent

A Real Bipartite Graph!



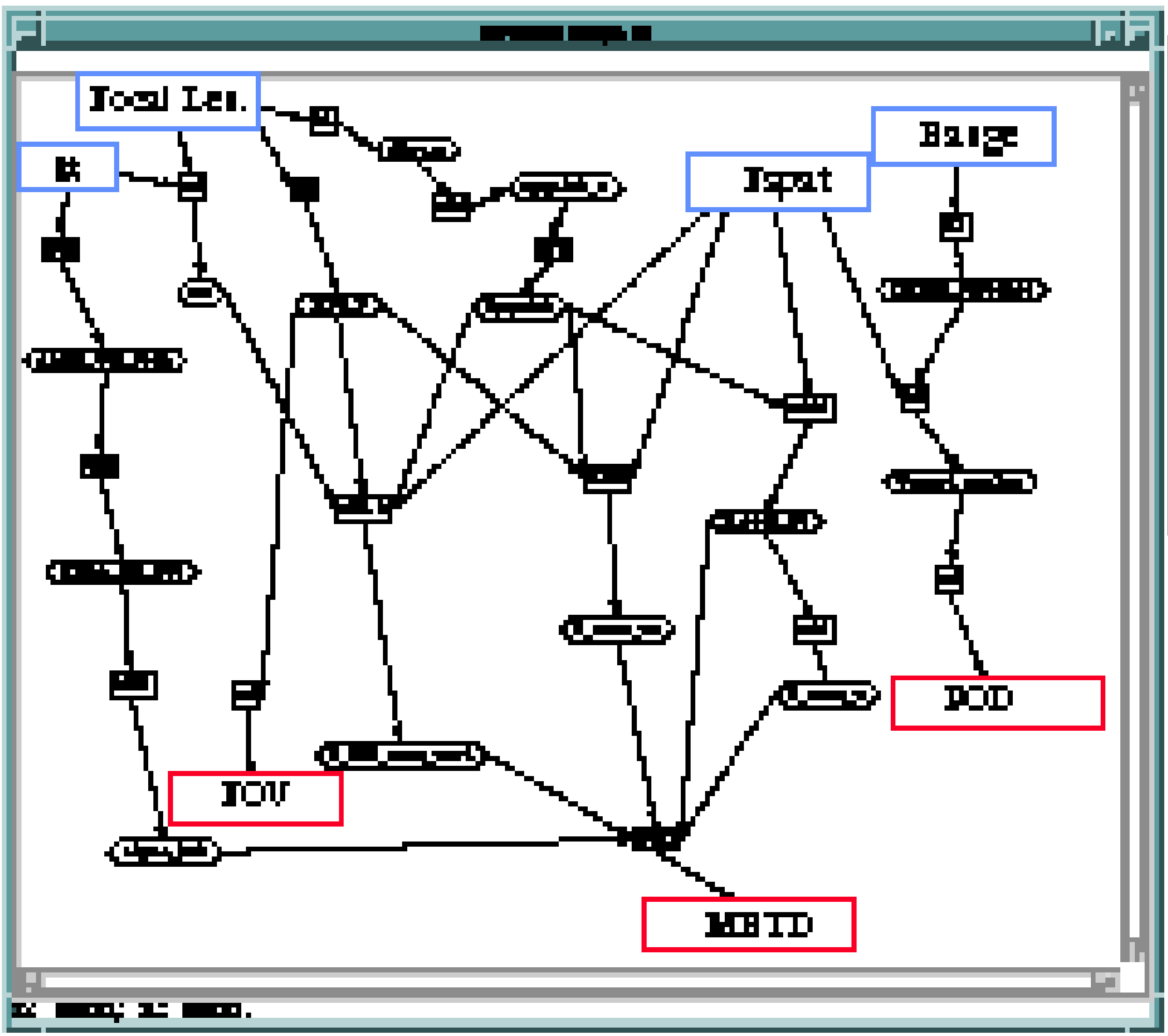
Example - Thermal Imaging System

Design Sheet was used to build a trade model for system-level trades on thermal imaging systems. The equations from FLIR92, developed by the U. S. Army Night Vision and Electronic Sensors Directorate



Light from the target on the left is gathered by the optics, strikes the Focal Plane Array, is converted into electronic signal, processed and displayed

A Partial Constraint Network



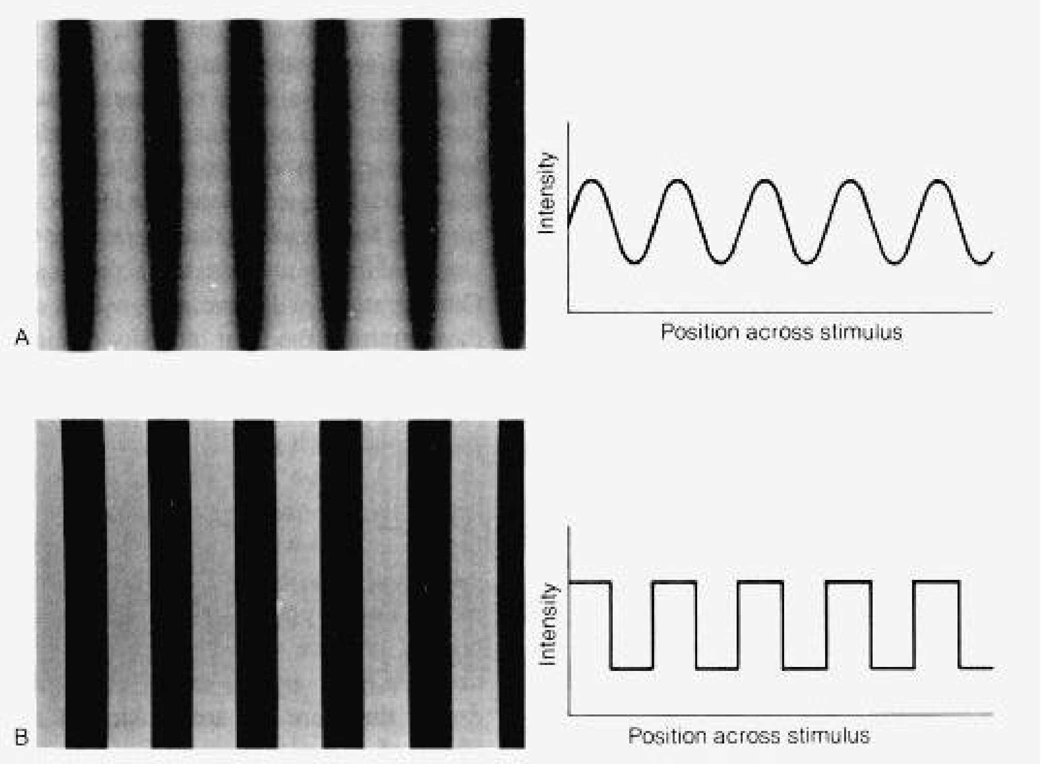
A partial constraint network w/ Performance Parameters: Field of View (FOV), Probability of Detection (POD) & Minimum Resolvable Temperature Difference (MRTD)

Design Parameters are focal length & f-stop (f/#)

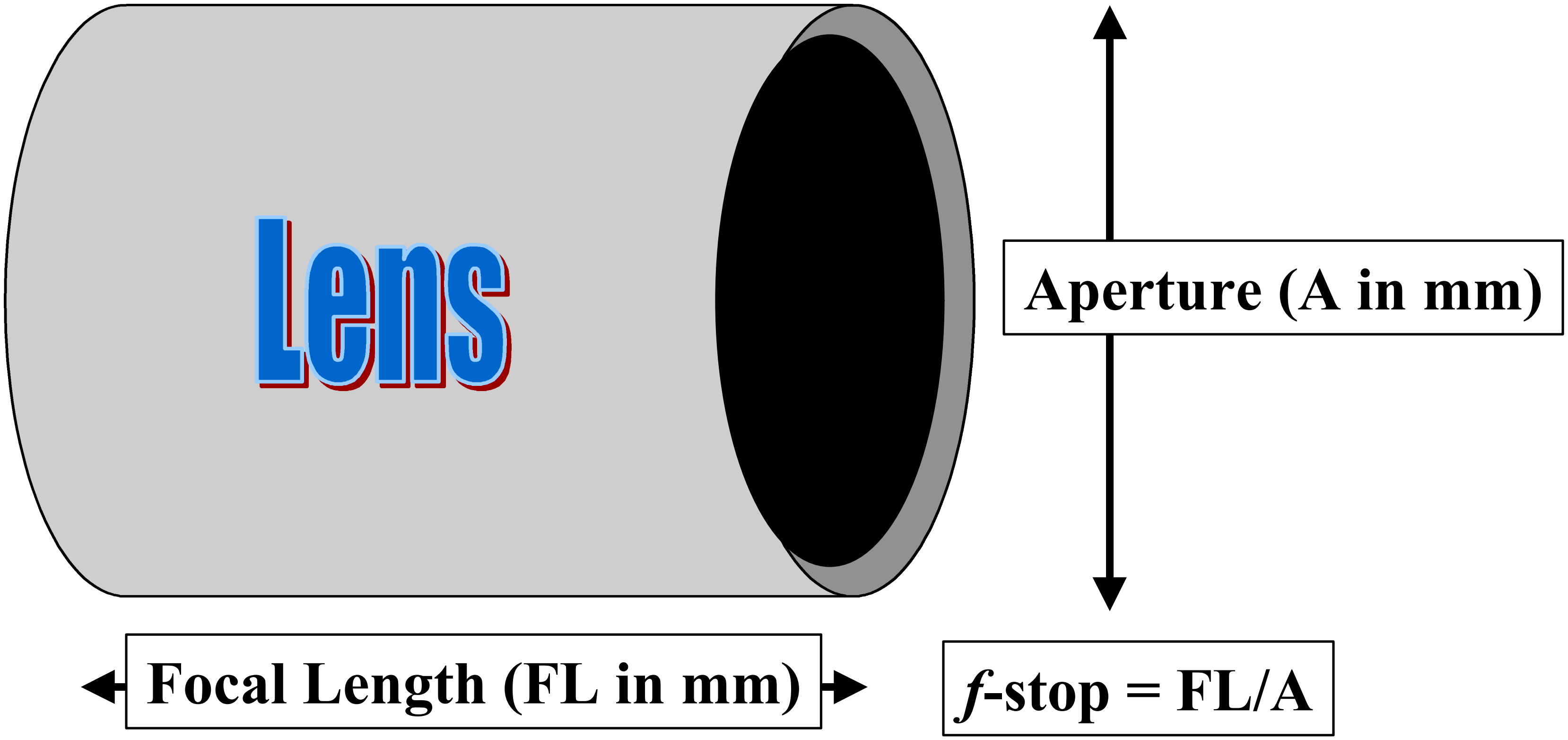
Operational Characteristics are target range and spatial frequency (Fspat)

Spatial frequency (fspat)

- Used for periodic stimuli (e.g., light) which vary in terms of wavelength (the distance between two adjacent peaks or troughs) or equivalently their frequency (the number of cycles, full periods of the wave, per unit distance)
- Usually fspat is expressed as number of cycles per degree (cpd) of visual angle



Focal length and *f*-stop



- ***f*-stop is variable, but a lens has a minimum *f*-stop governed by optics quality**
- **Field of view increases as A increases, decreases as FL and *f*-stop increase**

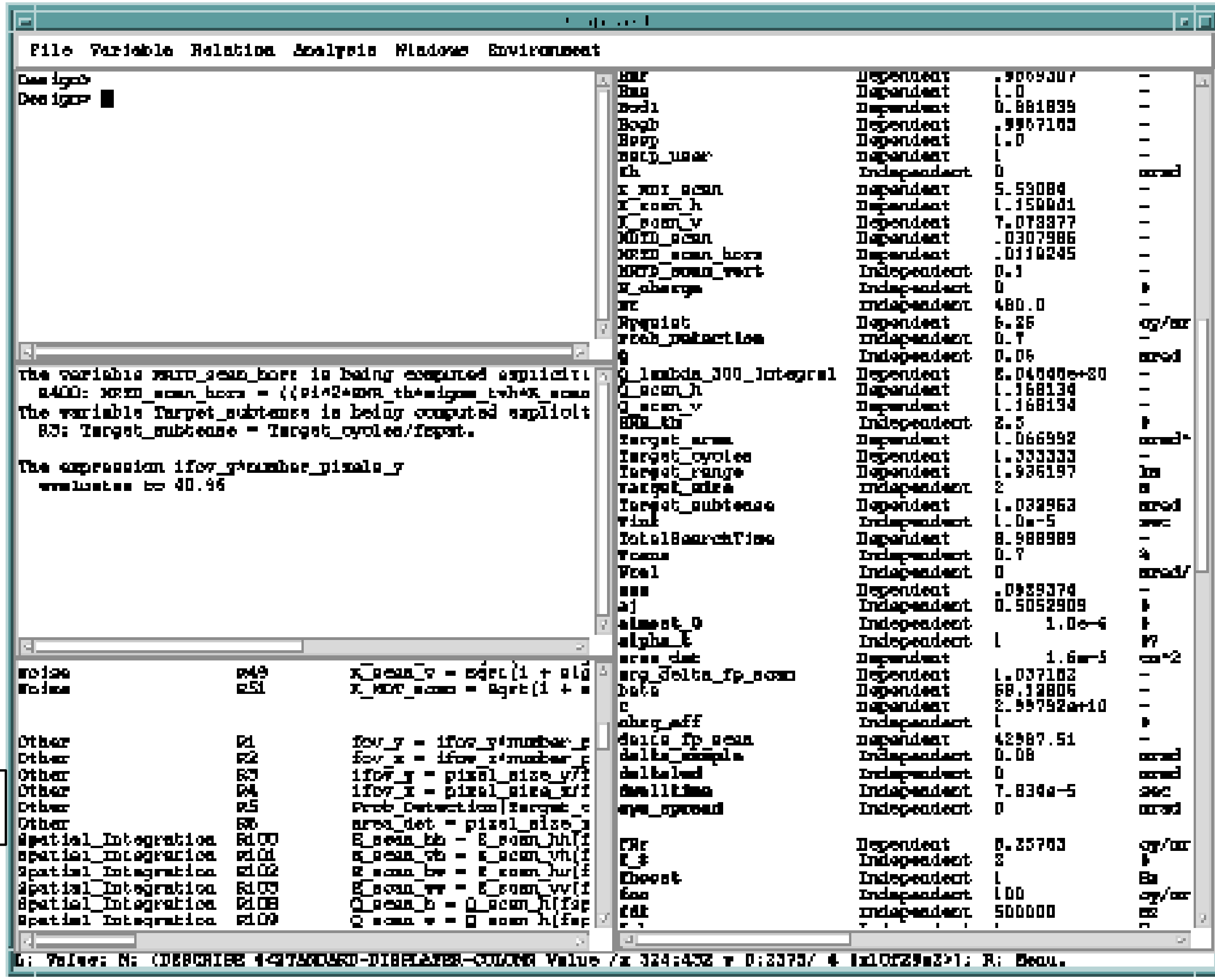
User Interfaces

Menu bar

Commands

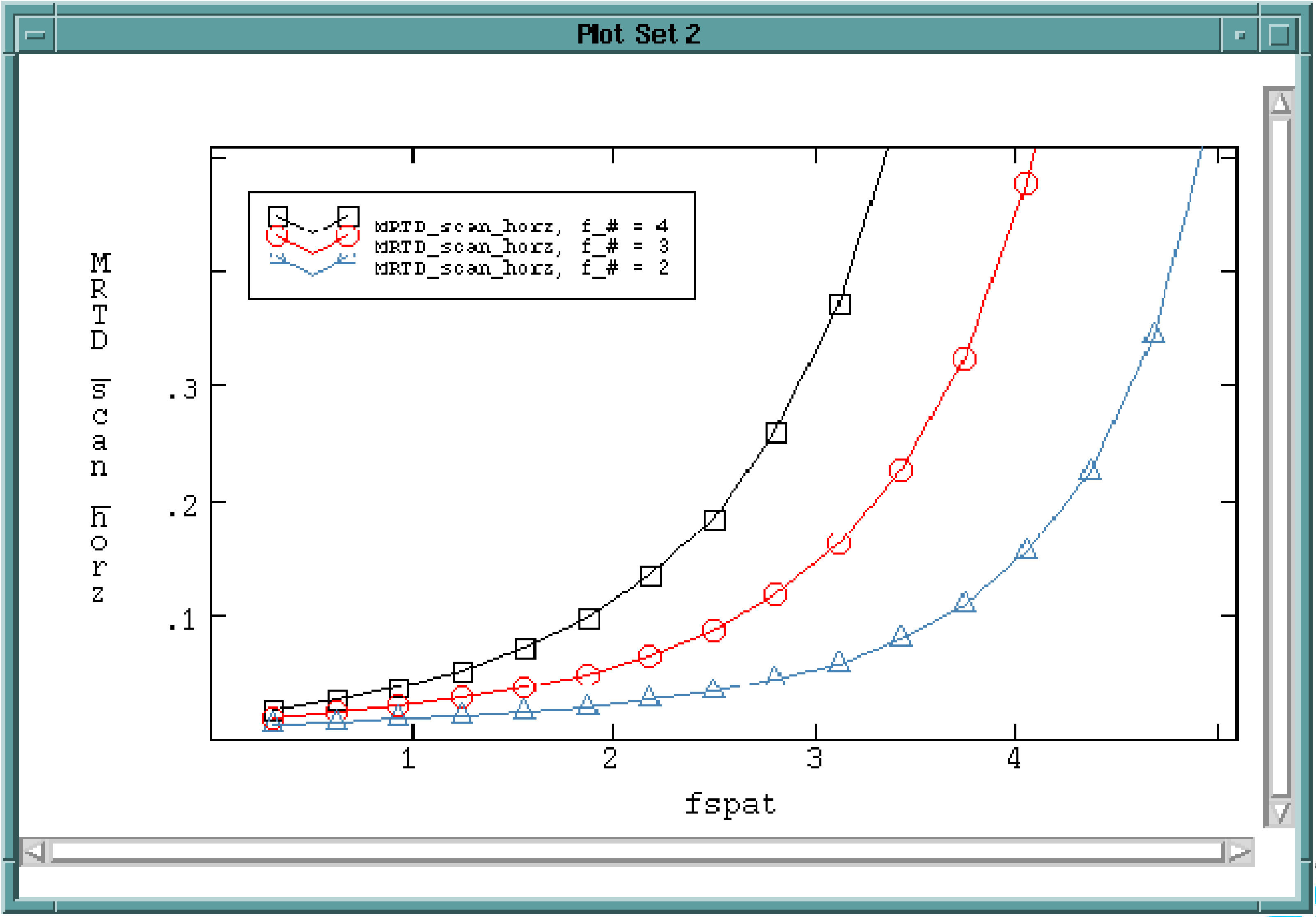
Display

Relationships

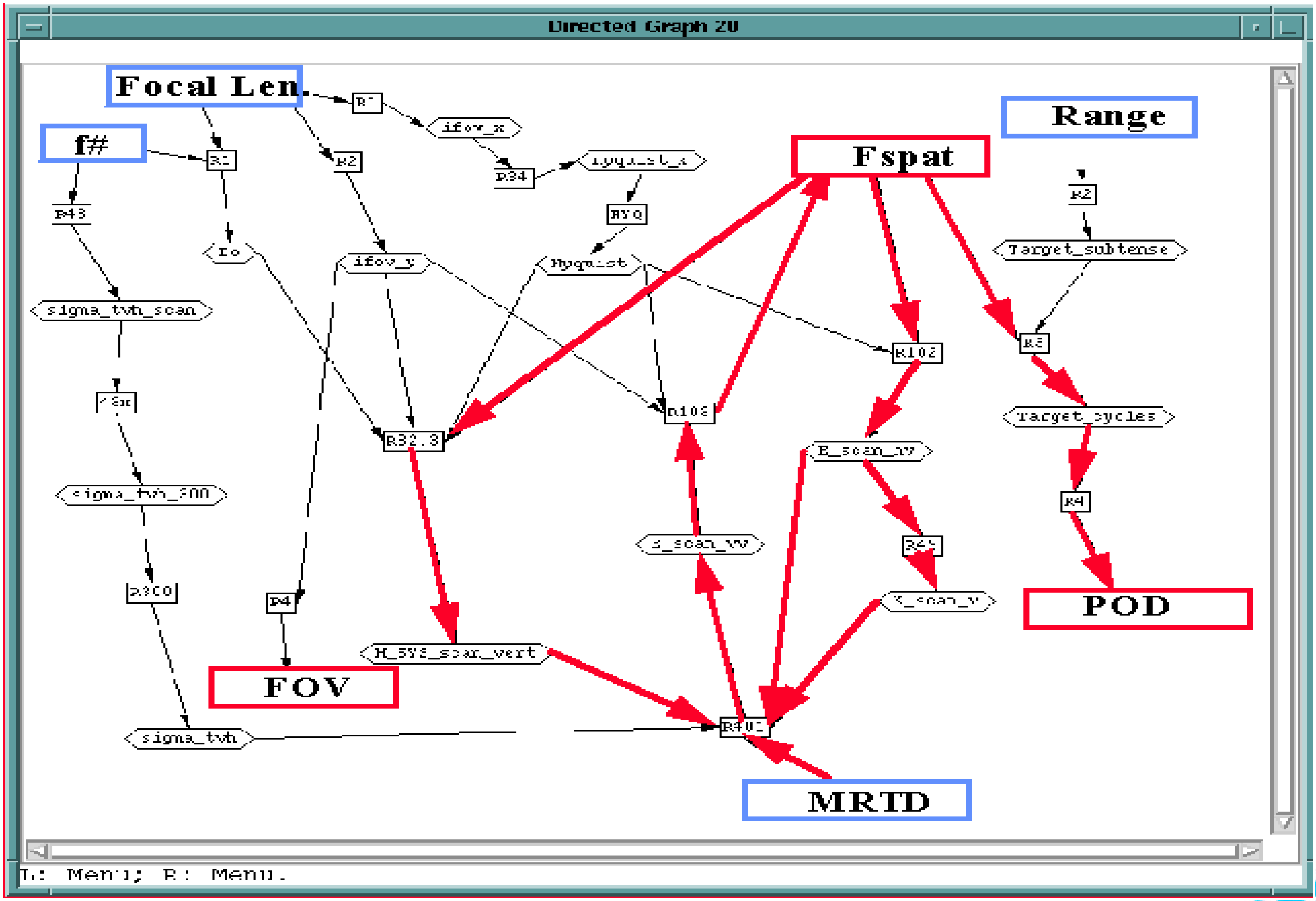


Variables spreadsheet

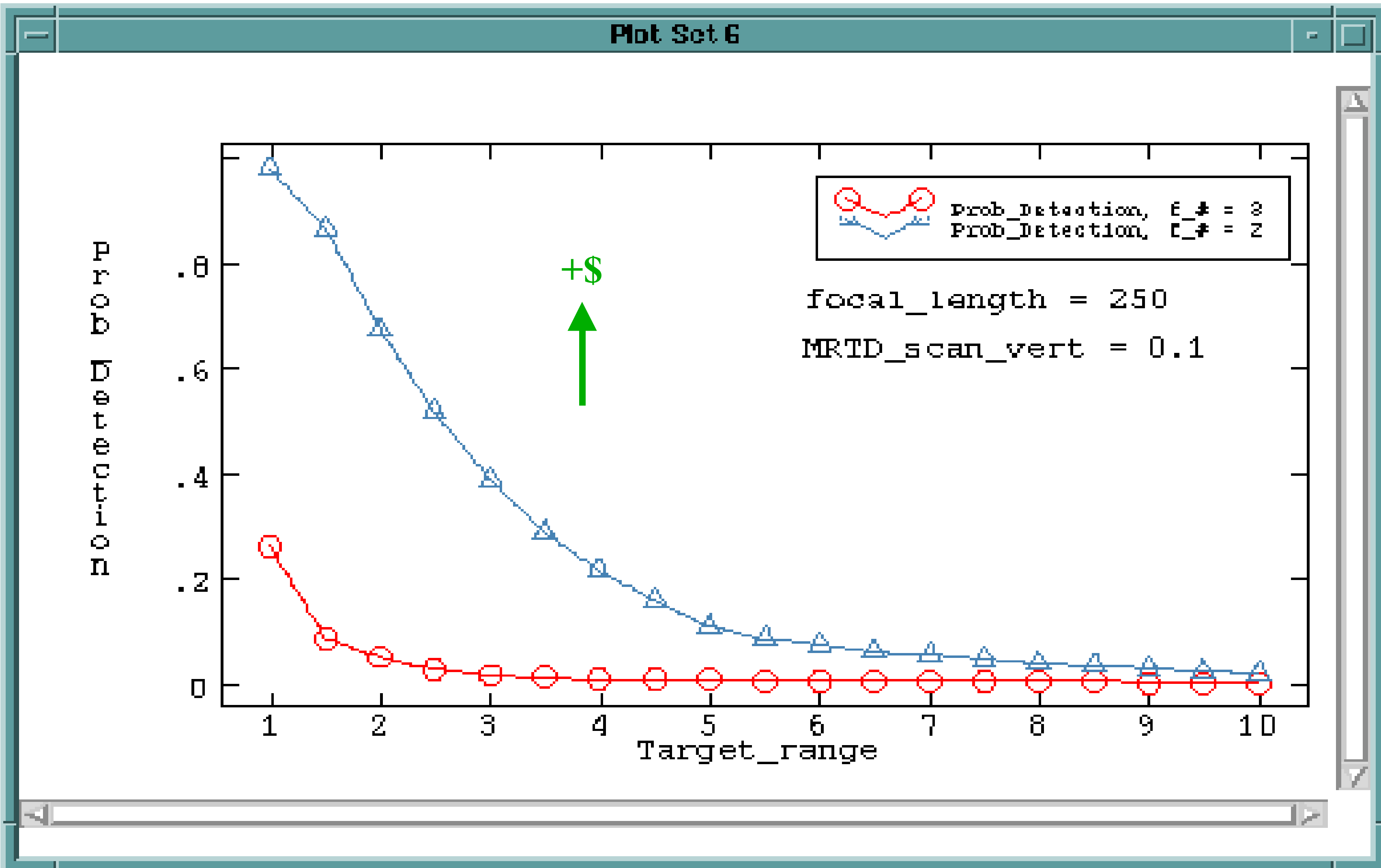
The effects of optics (FL=250, f/# = 2, 3, 4) on the trade between MRTD and spatial frequency   a traditional plot



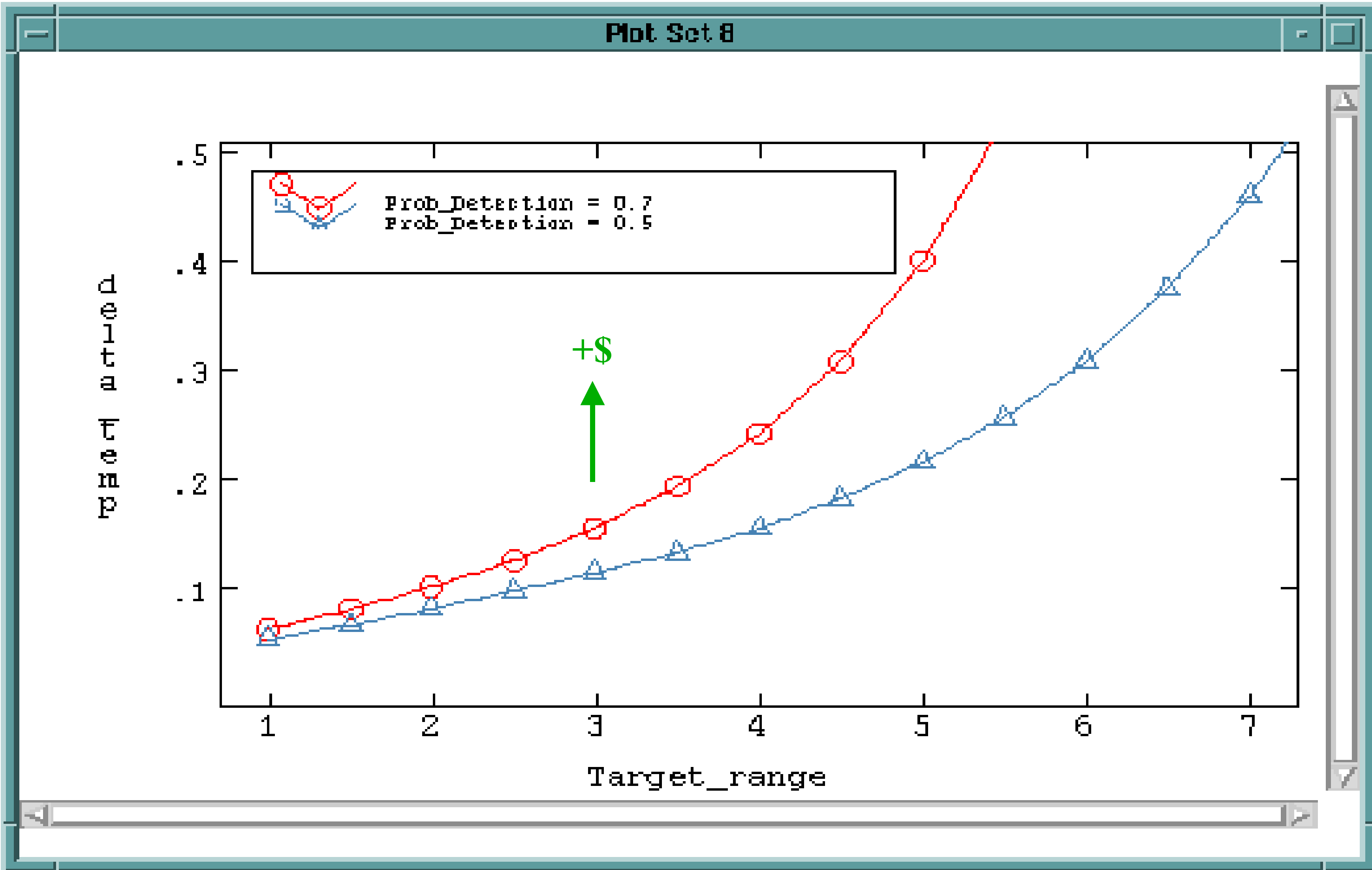
Reversed relationship - MRTD as an input to trade POD w/ Range



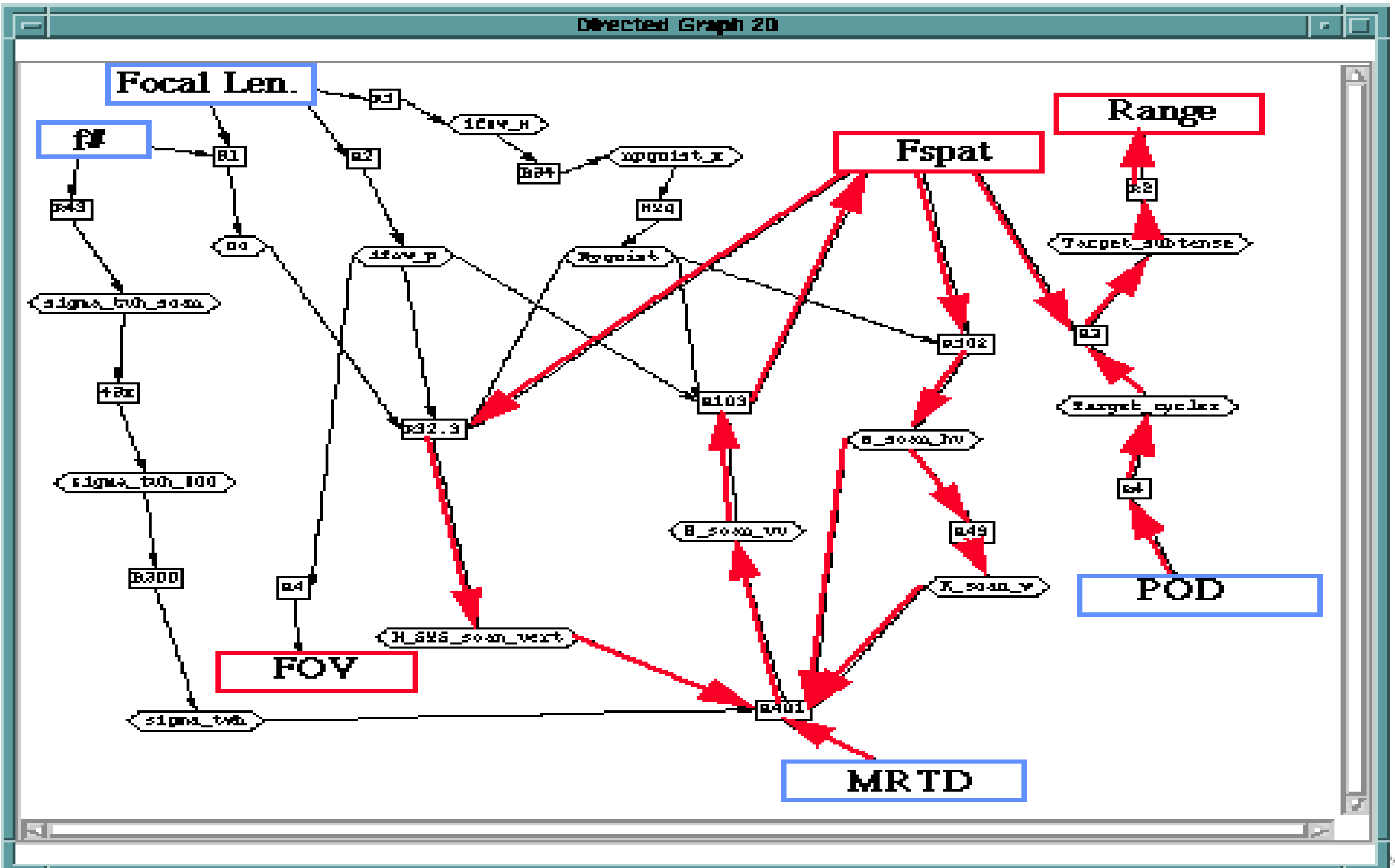
MRTD (and FL, f/#) as an input to trade POD & Range



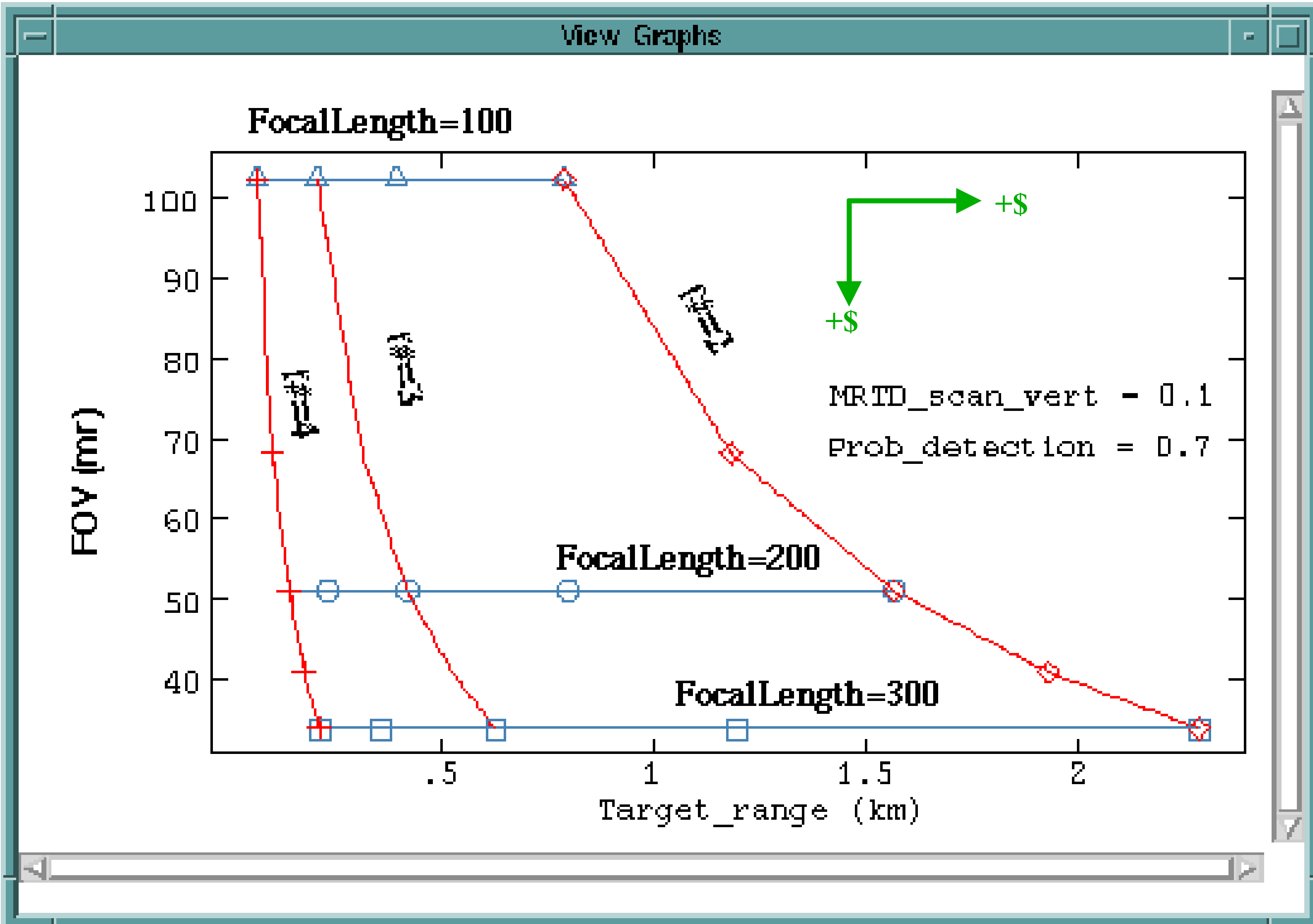
Trades of temperature delta w/ range for given POD



MRTD and POD Independent



Trading FOV w/ MRTD and POD Independent (cont d)



Conclusion

- Design trades are required by CAIV policy
- Trades are complicated by Non-comensurability
- Risk should be added or subtracted from other parameters or values, to fold it in
- Models such as Design Sheet are available to facilitate trades
  - The ACE has 5 site licenses for Design Sheet
  - The first DS workshop was in late April. To sign up for another, contact the briefer. Seats are very limited.

Sources

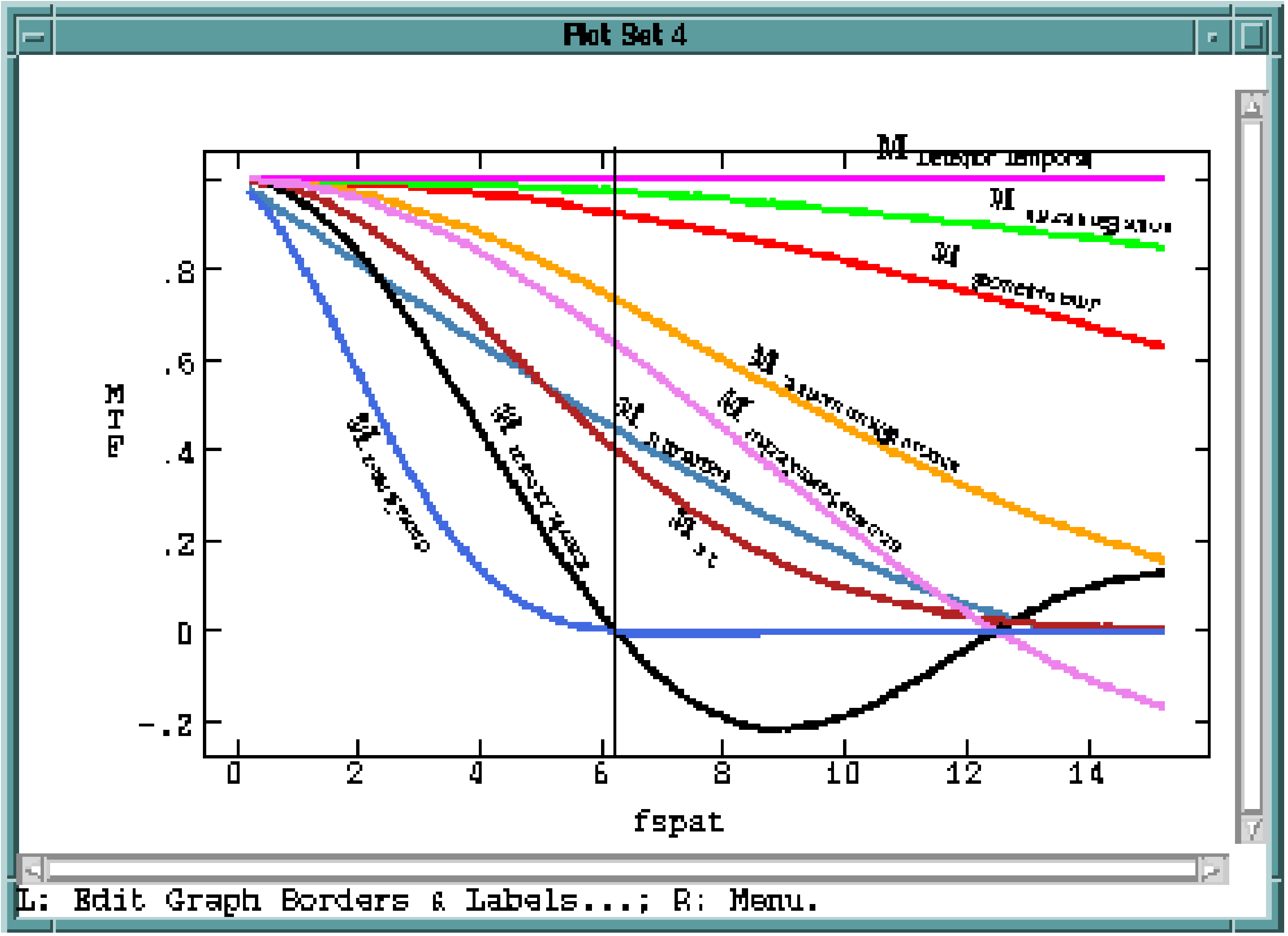
- **Design Sheet is under continuing development at the Rockwell Palo Alto Laboratory**
- **Major sources of support include Rockwell IR&D and DARPA funding under the Rapid Design Exploration and Optimization (RaDEO) program**
- **This brief was developed from the below papers:**

Constraint Management Methodology for Conceptual Design Tradeoff Studies
Sudhakar Y. Reddy, Kenneth W. Fertig and David E. Smith
Science Center, Palo Alto Laboratory
Rockwell International Corporation
August 18-22, 1996

Facilitating Infrared Seeker Performance Trade Studies Using Design Sheet
Sudhakar Y. Reddy and Kenneth W. Fertig
Rockwell Science Center, Palo Alto Laboratory, Palo Alto, California
and
Anne Hemingway
Rockwell International, Tactical Systems Division, Duluth, Georgia
September 25, 1995

Backup

MTF vs. Fspat


Plot Set 4
MTF
.8
.6
.4
.2
0
-.2
0
2
4
6
8
10
12
14
fspat
L: Edit Graph Borders & Labels...; R: Menu.

Spatial frequency

- Contrast is a measure of the intensity difference between different points in an image. One characterization of contrast is (maximum intensity - minimum intensity)/(average intensity) This is an especially useful measure of contrast when our stimuli are periodic (repetative) patterns such as sine-wave gratings or square-wave gratings (as in the picture below). In these cases contrast is often expressed as (max - min)/(max + min); this value ranges from 0 to 1. Periodic stimuli of this sort vary in terms of their wavelength (i.e., the distance between two adjacent peaks or troughs; see our discussion of light) or equivalently their frequency (i.e., the number of cycles, full periods of the wave, per unit distance). Usually frequency is expressed in terms of number of cycles per degree (cpd) of visual angle.