Whips and Chains, "Bring Me a Rock," and "DRIP": A Framework for Understanding Decision Analysis and Decision Support Information

NDIA Systems Engineering Division 15th Annual Conference

24 Oct 2012

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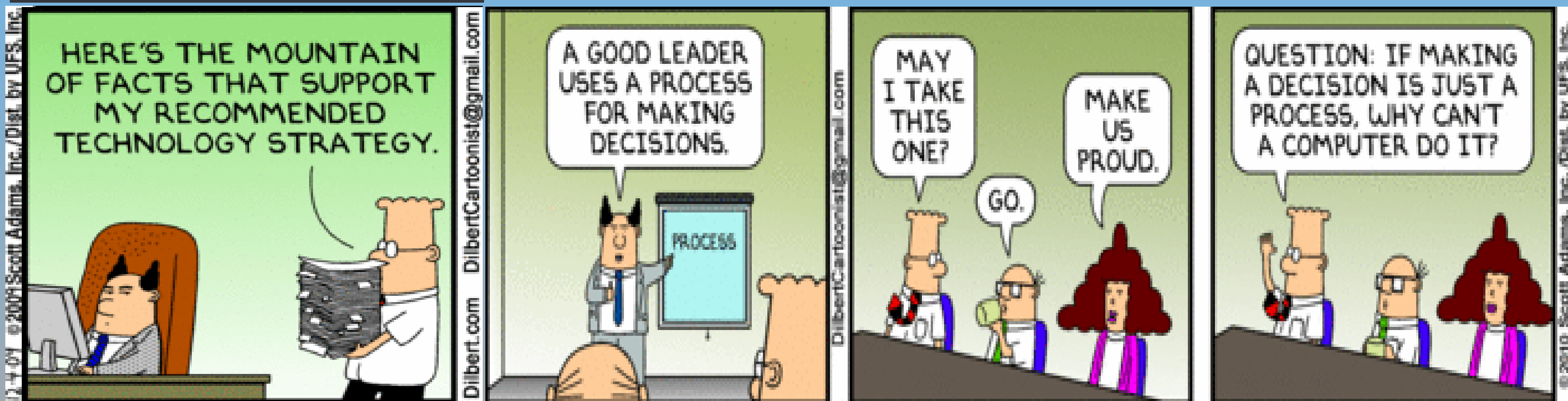
ON TAP ...

- Why Worry?
- Definitions
  - Decision Analysis
  - Decision Support Information
- Scenario: Recommend a Preferred Alternative
  - Whips and Chains
  - "Bring Me A Rock"
- Scenario: Trades
  - "DRIP"
- Glossary: Decision Analysis, A to X
- Why It's Important

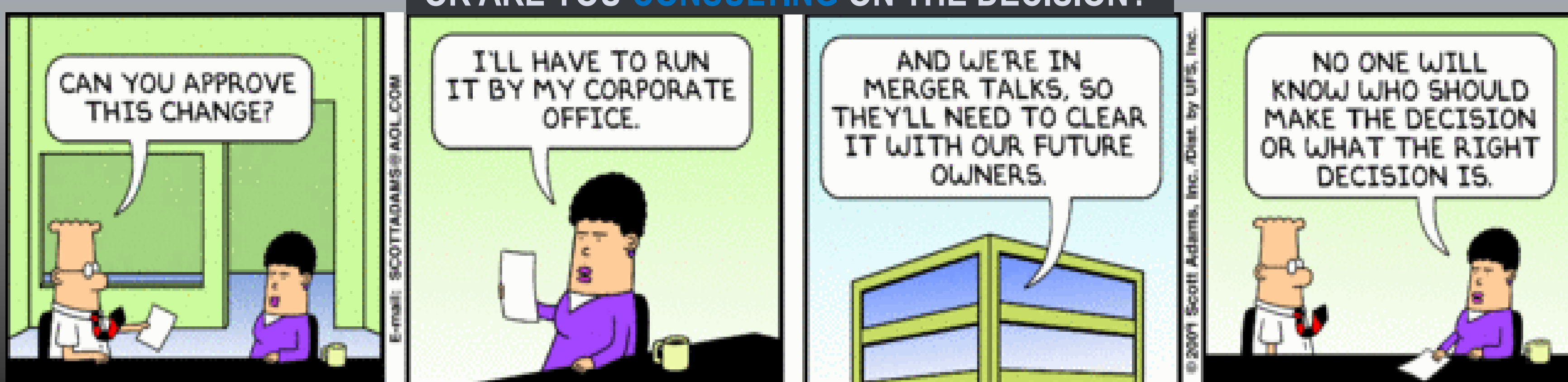
WHY WORRY ABOUT DECISION ANALYSIS AND DECISION SUPPORT INFORMATION?

IT DEPENDS ... ARE YOU **ADVOCATING A POSITION** FOR THE DECISION ?

ARE YOU **RESPONSIBLE OR ACCOUNTABLE** TO ACTUALLY MAKE THE DECISION ?



OR ARE YOU **CONSULTING** ON THE DECISION?

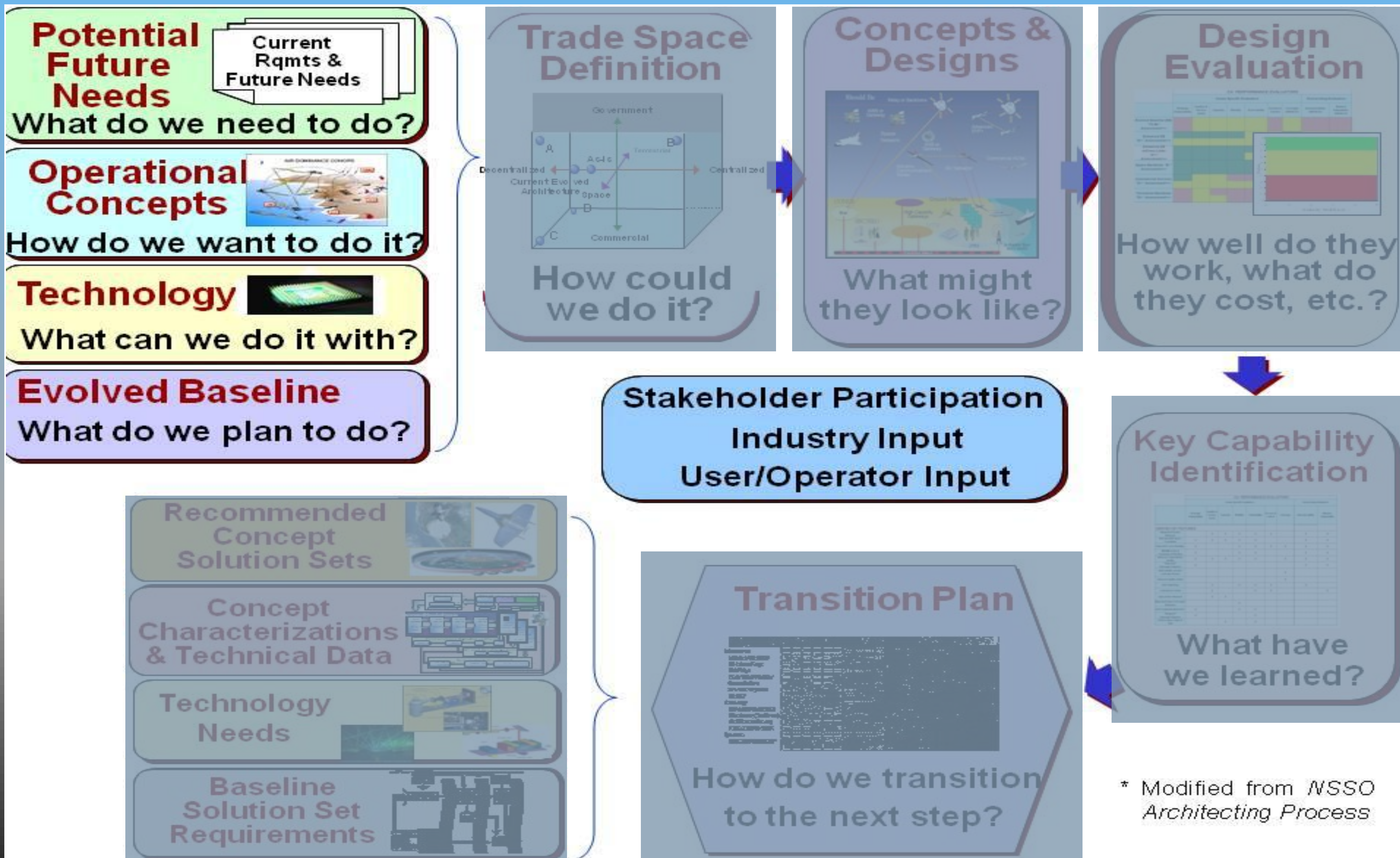


DEFINITIONS – FOR PURPOSES OF THIS PRESENTATION

- **Decision Analysis** is a method (or a collection of methods) for evaluating a set of options against a set of established criteria, documenting each choice made along with its supporting rationale, and packaging the results (data) in a form or format that facilitates the customer's ability to make the decision at hand.

- **Decision Support Information** captures extracts from the technical and analytical knowledge base of the item(s) under review. While any individual data element by itself may be of limited – or extreme – value, the aggregation and sequencing of the elements are what produce actionable and usable information for the decision makers.

WHAT QUESTIONS DO WE WANT TO ANSWER, AND WHEN? WHAT MATERIAL SHOULD WE PROVIDE?



DECISION ANALYSIS STEPS MAPPED TO CLASSIC PROCESS STEPS

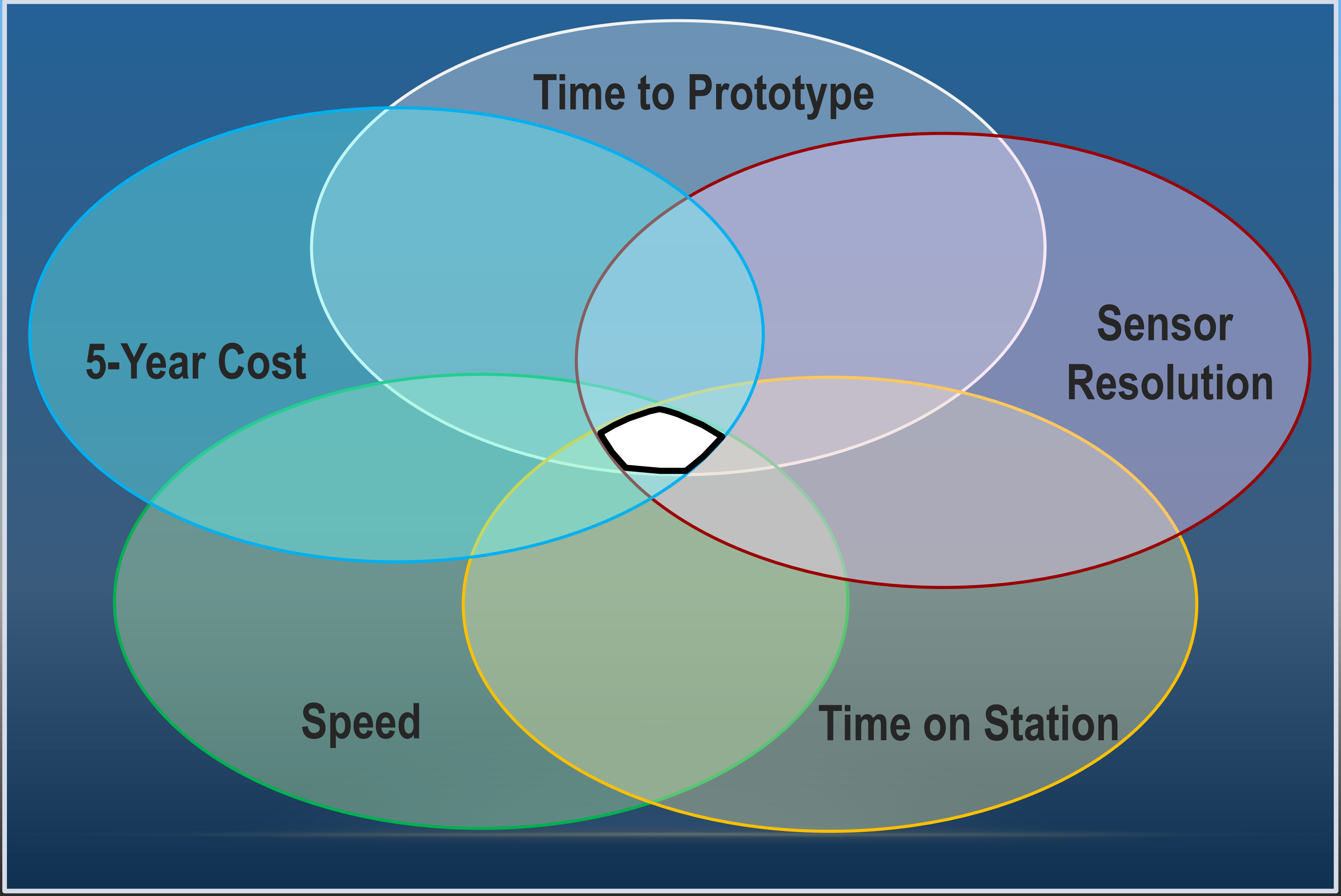
PLAN	Review requirements and assumptions Establish overall decision context Frame decision in terms of objectives Identify methods and tools Develop decision criteria (objectives/measures) and rationale
DO	Identify and define alternatives Analyze and assess alternatives Synthesize results and document decisions
CHECK (STUDY)	Analyze sensitivities
ACT	Develop decision briefing with action/implementation plan(s) Make recommendation(s) to decision-maker(s)

WHIPS AND CHAINS

- "If you torture data long enough, it will tell you anything you want to hear." *adapted from Ronald Coase, unpublished*

- Scenario / Task (next slide)
  - Four system concepts under review
  - Five evaluation factors
  - Analysis team must assign weights to factors; weights sum to 10
  - Analysis team must recommend a preferred alternative

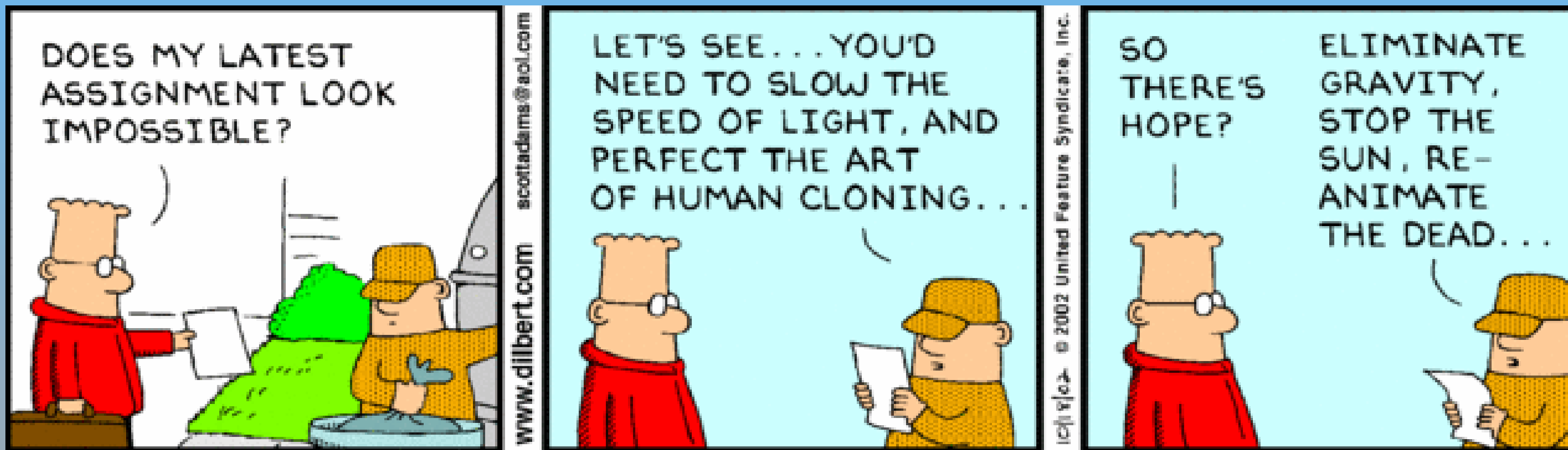
ONE SCENARIO – RECOMMEND A PREFERRED ALTERNATIVE



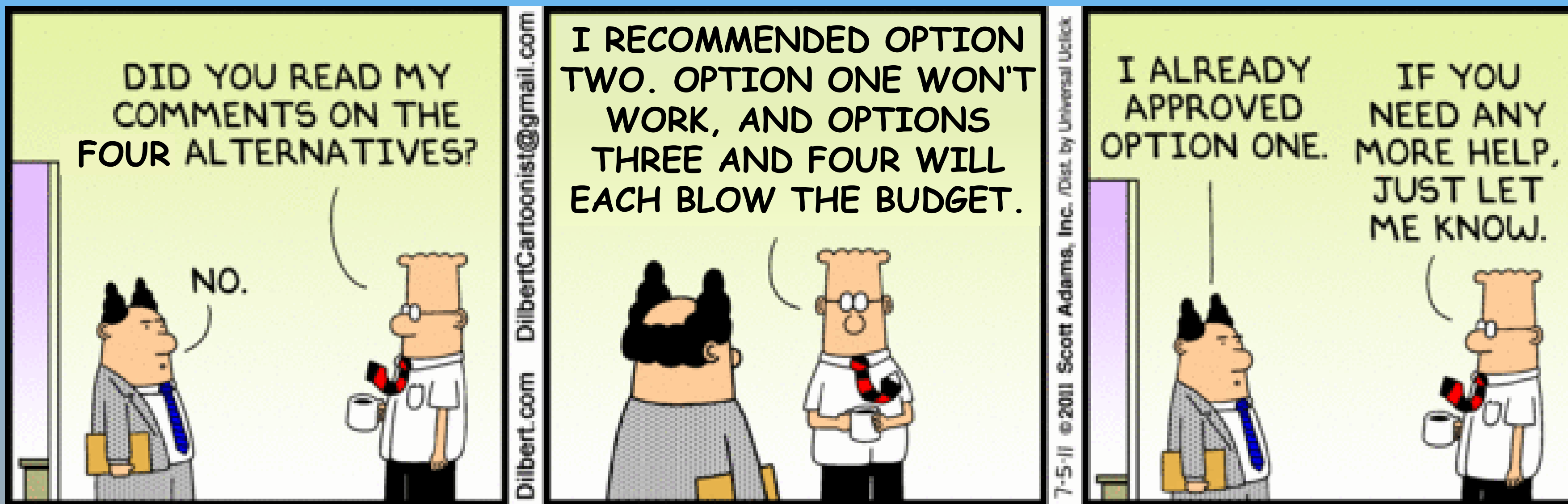
INSTRUMENTS OF TORTURE

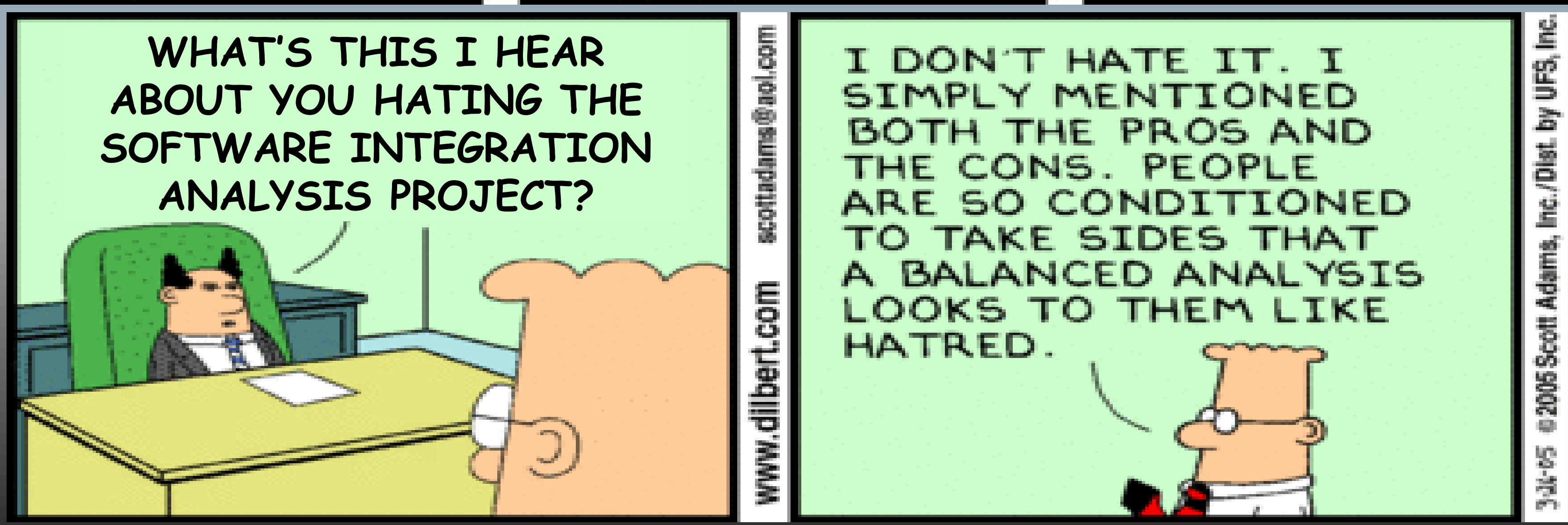
- Numerous stakeholder communities want to ensure that the decision makers consider their interests
- Numerous external entities, often with only peripheral interest in either the process or the actual decision, often exert pressure on one or both
- Worse, many of these overt and peripheral stakeholders often have conflicting – if not mutually exclusive – views
- Analysts may therefore feel pressure to manipulate and present data to depict what the audience wants or expects to see or hear

The Process Has Its Challenges ... From Start To Finish



... And The Process Demands Integrity





NOTIONAL DECISION MATRIX

- In this scenario, the analysis team would likely recommend System 4 as the preferred alternative, even though all scores are reasonably close

Decision Factors / Weights	Time to Prototype Test		5-Year Cost		Sensor Resolution		Speed		Time on Station		Weighted Totals
Weights	2.5		2.0		1.5		1.5		2.5		
Alternatives	Scores (U = Utility value; W = Weighted value)										
	U	W	U	W	U	W	U	W	U	W	
System 1	.6	1.5	.7	1.4	.8	1.2	.7	1.05	.6	1.5	6.65
System 2	.7	1.75	.5	1.0	.7	1.05	.8	1.2	.7	1.75	6.75
System 3	.8	2.0	.8	1.6	.6	0.9	.7	1.05	.5	1.25	6.8
System 4	.7	1.75	.6	1.2	.5	0.75	.6	0.9	.9	2.25	6.85

REVISED DECISION MATRIX

- If the analysts think – or are led to believe – that the customer values cost more highly than time on station, they are more likely to recommend System 3

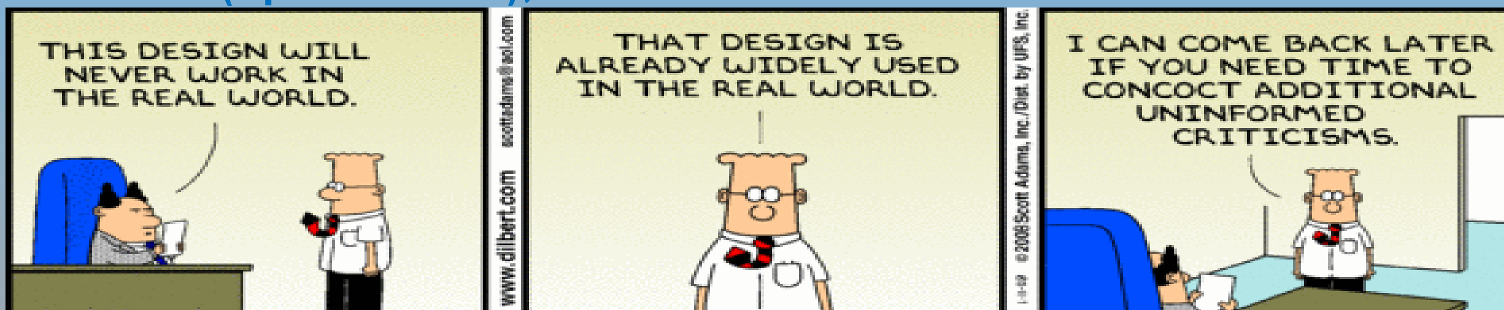
Decision Factors / Weights	Time to Prototype Test		5-Year Cost		Sensor Resolution		Speed		Time on Station		Weighted Totals
Weights	2.5		2.5		1.5		1.5		2.0		
Alternatives	Scores: U = Utility value, W = Weighted value										
	U	W	U	W	U	W	U	W	U	W	
System 1	.6	1.5	.7	1.75	.8	1.2	.7	1.05	.6	1.2	6.7
System 2	.7	1.75	.5	1.25	.7	1.05	.8	1.2	.7	1.4	6.65
System 3	.8	2.0	.8	2.0	.6	0.9	.7	1.05	.5	1.0	6.95
System 4	.7	1.75	.6	1.5	.5	0.75	.6	0.9	.9	1.8	6.7

"BRING ME A ROCK"

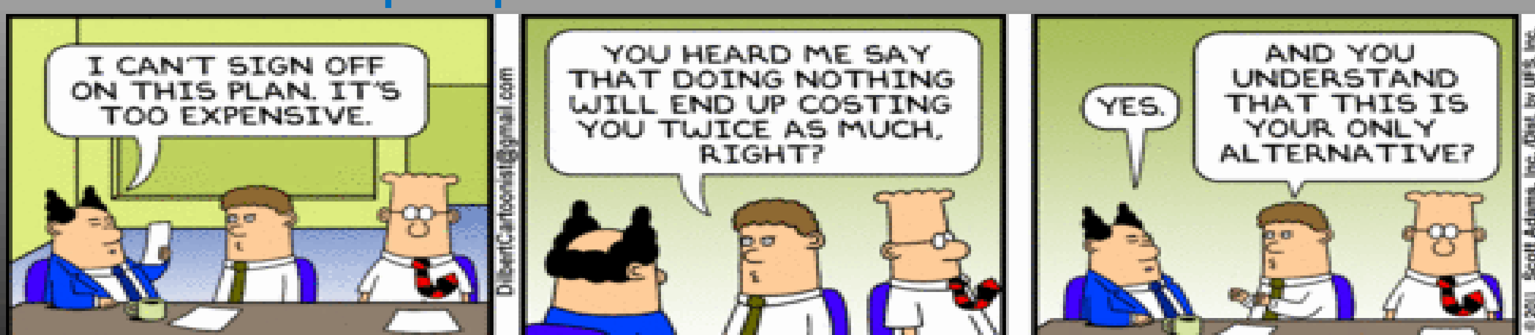
- Generally appears as feedback from the decision-maker(s) after the briefing or presentation
- The analysts may have attempted to accommodate (or at least not antagonize) as many interests as possible, by attempting to craft a consensus "one-size-fits-all" recommendation
- Reviewers and/or decision makers may feel dissatisfied with the adequacy of the analysis (perhaps in scope; perhaps in maturity; perhaps in detail; perhaps other aspects)
  - The difficulty is that they may not know – or be able to articulate – what specific additional information might scratch that itch
  - Analysts need to appropriately distill the feedback and determine which aspects of the analysis and associated trades need to be re-examined
  - The process tends to repeat until the decision-makers agree on what is REALLY important

SOME COMMON ROCKS …

- “What can you do sooner?”
  - You can’t schedule technology or innovation
- “It has to be different” -- bigger (smaller), faster (slower), lighter (heavier), secure (open-source), etc.

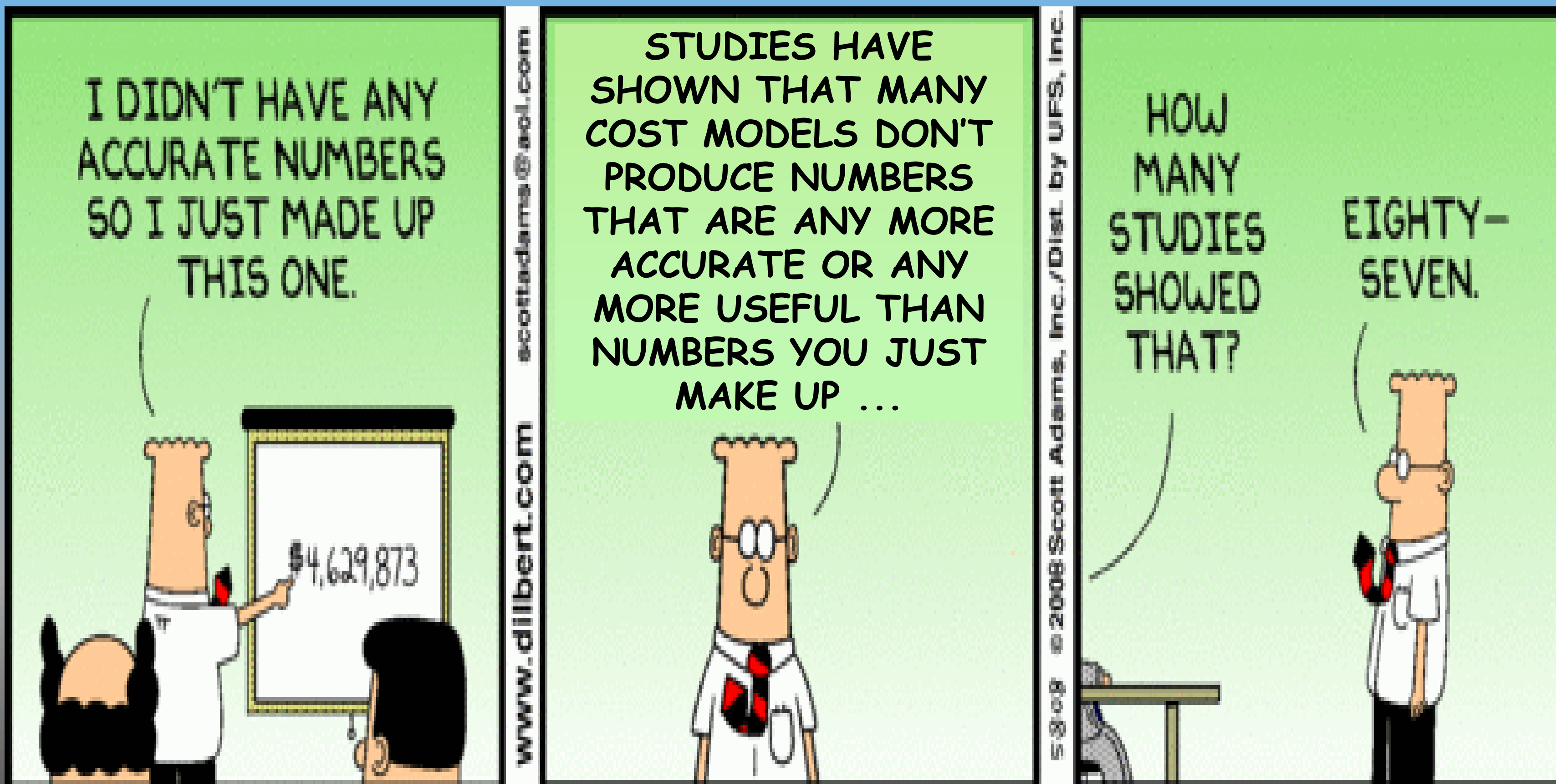


  - What other parameter(s) are you willing to trade?
- “What’s a cheaper option?”

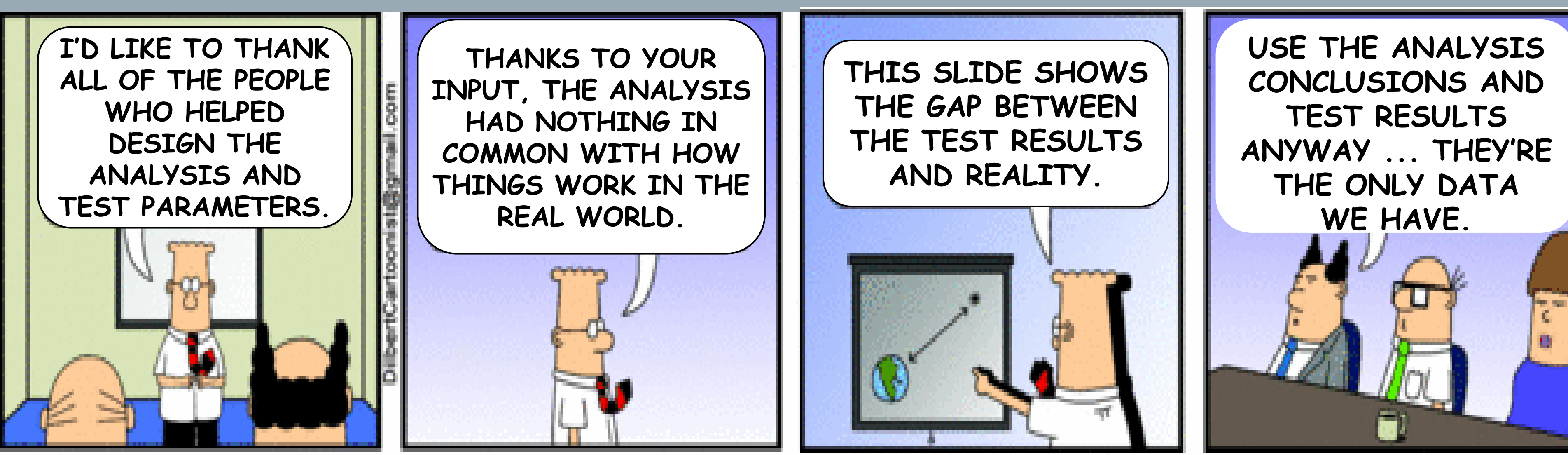


  - What are you willing to trade?

Be Careful What You Ask For ...



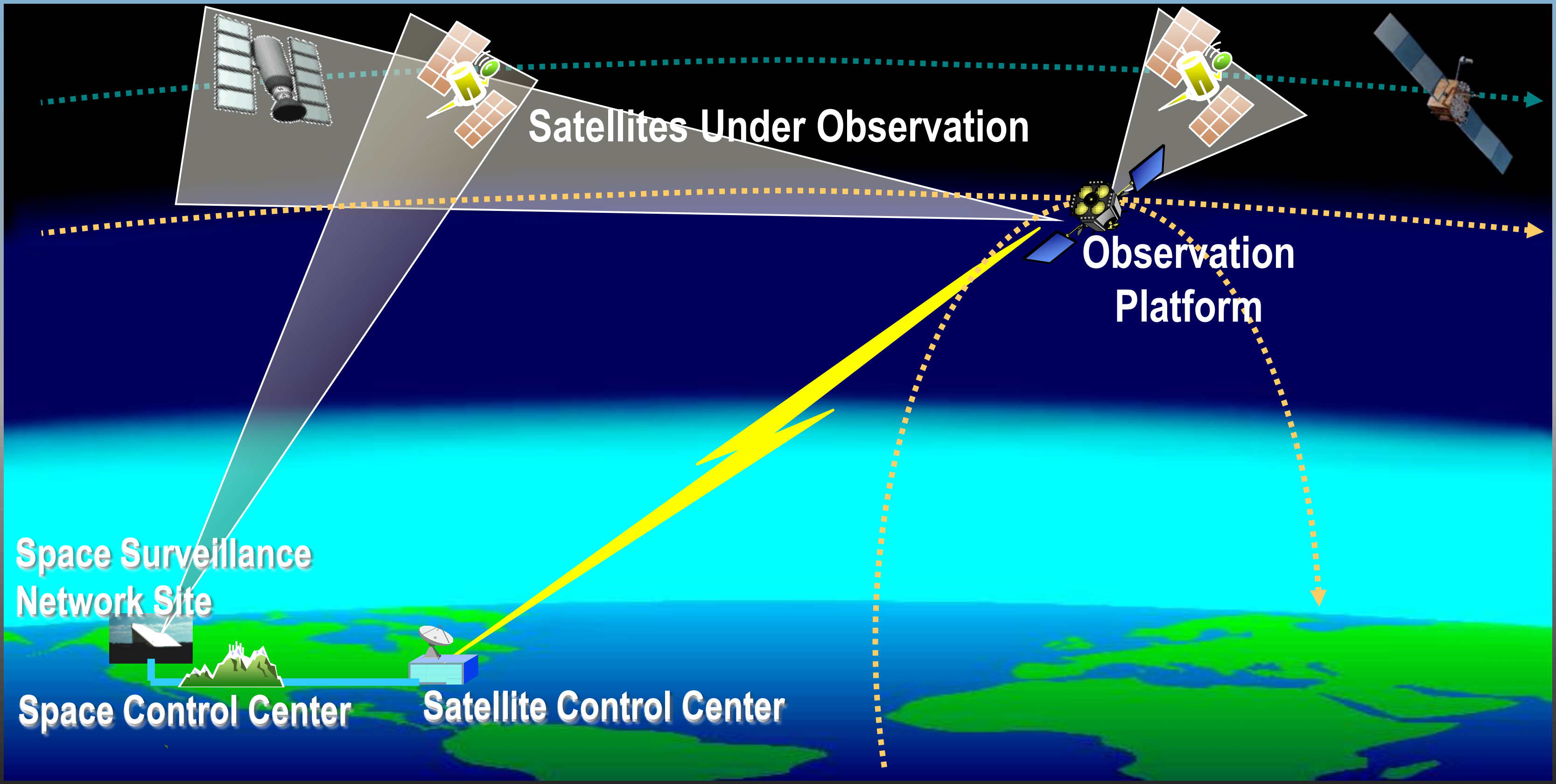
... Because Sometimes the Truth Hurts



DATA-RICH, INFORMATION-POOR (aka “DRIP”)

- Too often, analysts’ response to vague requests for data (from either management or decision makers) is simply to inundate the requester in a flood of plots and spreadsheets

- CASE STUDY: Space Situational Awareness (SSA) Architecture Characterization



Adapted from SMC/XRD “PASEP” study, 2006-2008

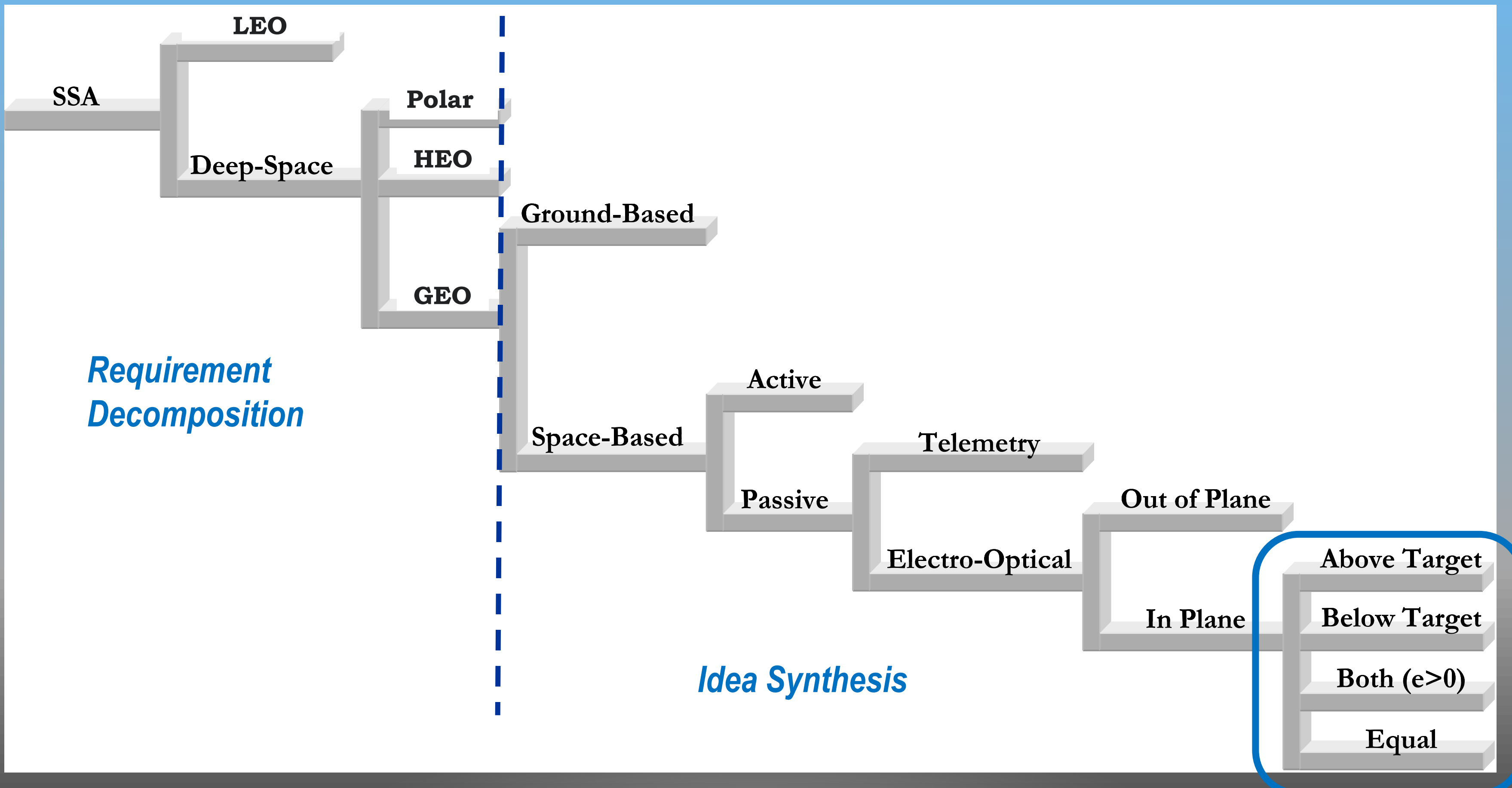
SSA TASK: FIND, TRACK, IDENTIFY ALL OBJECTS IN EARTH ORBIT

- **What does "orbit" mean?**
  - Low Earth Orbit (LEO)
  - Highly Eccentric Orbit (HEO)
  - Geosynchronous Orbit (GEO)
  - Polar Orbit
- **Are there any obvious constraints?**
  - How long should "Track" be maintained?
  - How much resolution is needed to "Identify"?

- Once an **architectural analysis scoped the problem** and determined that this SSA system should only examine objects in **GEO**, system-level trades assessed various characteristics of both space-based and ground-based systems

Adapted from SMC/XRD "PASEP" study, 2006-2008

DECISION TREE FOR SPACE-BASED SSA SYSTEM



Adapted from SMC/XRD "PASEP" study, 2006-2008

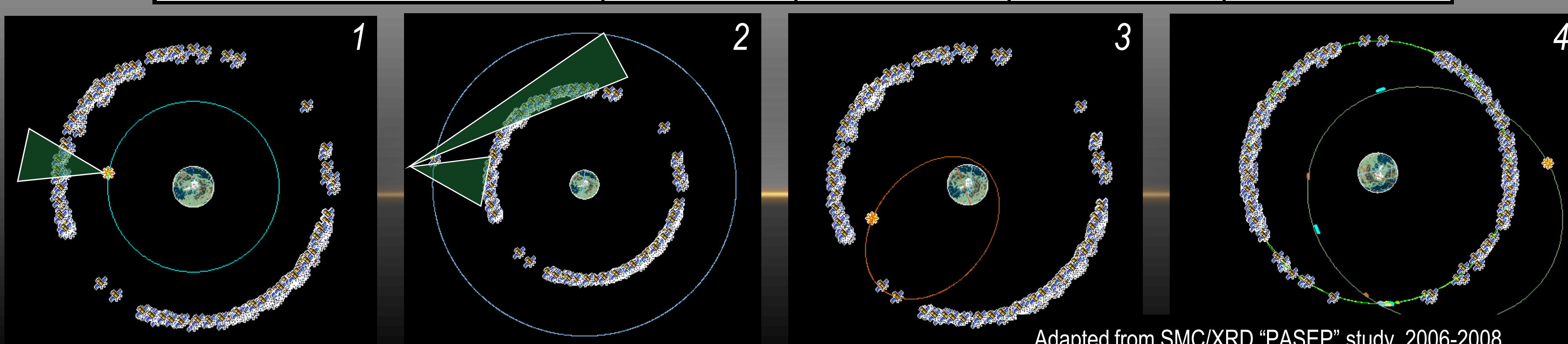
KEY TRADES - ORBIT

Metric	Near-Synchronous Circular Orbits	Synchronous Apogee, Highly Eccentric Orbits
Close Approach %	Best percentage of close approaches in a given time	Acceptable percentage of close approaches
Launch Delta-V	Normal GEO launch parameters	~1500 m/sec less than GEO
Wide-Field Imaging and Detection	Acceptable imaging performance	Best method for both imaging and detection

Adapted from SMC/XRD "PASEP" study, 2006-2008

TRADE SPACE & EXPLORATORY ANALYSIS

Figure	Orbit Type	a	e	apogee	Rating
3	Eccentric, Synchronous Apogee	24546 km	0.719791	42214 km	
	Eccentric, Synchronous Apogee	26584 km	0.587948	42214 km	
	Eccentric, Synchronous Apogee	32200 km	0.310994	42214 km	
	Eccentric, Synchronous Apogee	37684 km	0.12021	42214 km	
	Eccentric, Synchronous Apogee	39576 km	0.066657	42214 km	
	Eccentric, Synchronous Apogee	41254 km	0.0232705	42214 km	
	Eccentric, Synchronous Apogee	41855 km	0.0085772	42214 km	
	Eccentric, Synchronous Apogee	42010 km	0.004856	42214 km	
	Eccentric, Synchronous Apogee	42086 km	0.0030414	42214 km	
	Circular, Near Synchronous	42014 km	0	42014 km	
	Circular, Near Synchronous	42064 km	0	42064 km	
	Circular, Near Synchronous	42089 km	0	42089 km	
	Circular, Near Synchronous	42114 km	0	42114 km	
	Circular, Near Synchronous	42139 km	0	42139 km	
	Circular, Near Synchronous	42164 km	0	42164 km	
	Circular, Near Synchronous	42189 km	0	42189 km	
	Circular, Near Synchronous	42214 km	0	42214 km	
	Circular, Near Synchronous	42264 km	0	42264 km	
4	Super HEO	42164 km	0.5	63246 km	!!
1	Circular, Sub Synchronous	26600 km	0	26600 km	NA
2	Circular, Super Synchronous	67000 km	0	67000 km	NA



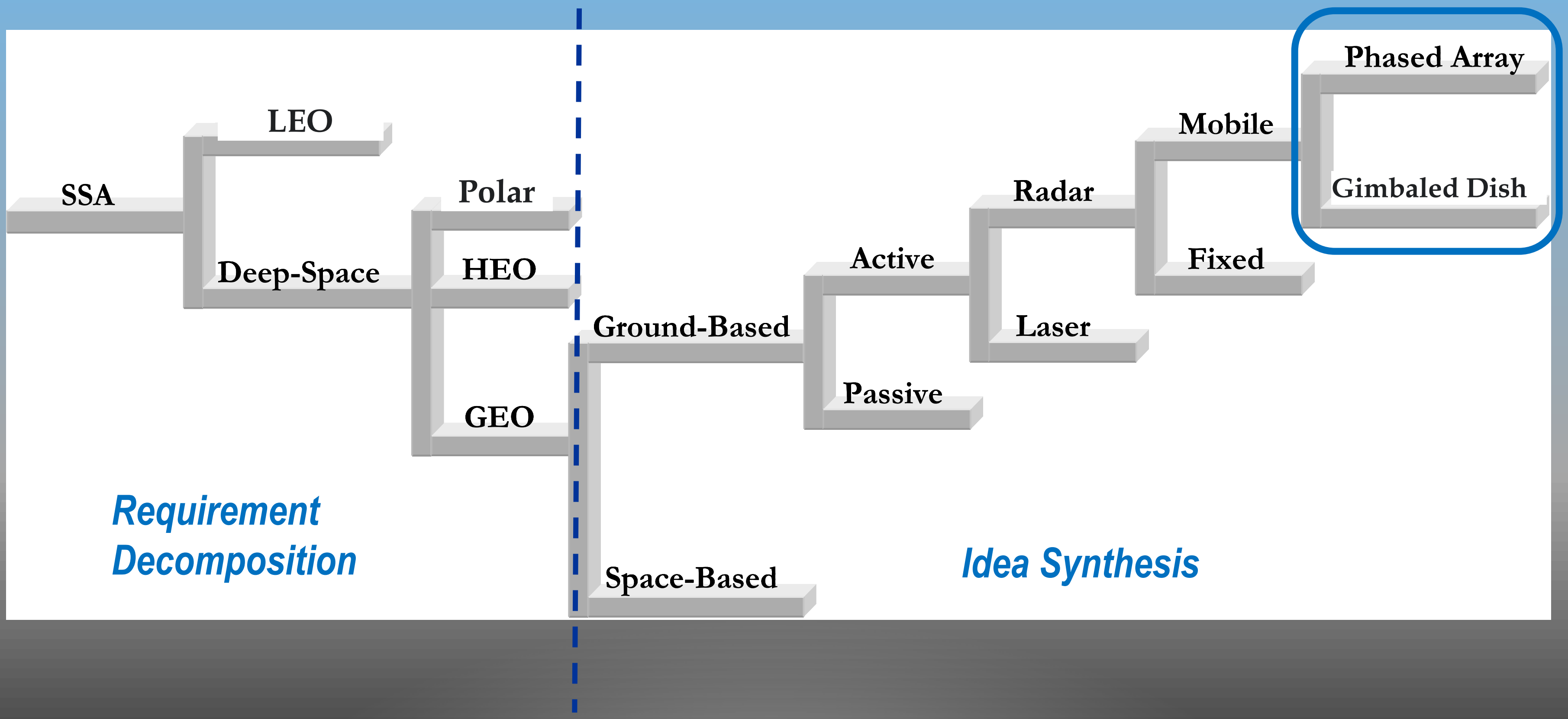
Adapted from SMC/XRD "PASEP" study, 2006-2008

SYSTEM AND SUBSYSTEM CHARACTERIZATION

	Configuration 1 50 cm Imager, Sub-GEO		Configuration 2 50 cm Imager, GTO		Configuration 3 10 cm Imager, Sub-GEO		Configuration 4 10 cm Imager, GTO		Configuration 5 50 cm Gimbal Imager, Sub-GEO		Configuration 6 50 cm Gimbal Imager, GTO		Configuration 7 10 cm Gimbal Imager, Sub-GEO		Configuration 8 10 cm Gimbal Imager, GTO	
	Mass		Mass		Mass		Mass		Mass		Mass		Mass		Mass	
	kg	lbm	kg	lbm	kg	lbm	kg	lbm	kg	lbm	kg	lbm	kg	lbm	kg	lbm
Payload Total	**106**	**233**	**106**	**233**	**69**	**152**	**69**	**152**	**117**	**257**	**117**	**257**	**74**	**164**	**74**	**164**
50 cm Imager	65	143	65	143					65	143	65	143				
10 cm Imager					33	73	33	73					33	73	33	73
Imager Gimbal																
Payload Communications	27	59	27	59	27	59	27	59	27	59	27	59	27	59	27	59
Payload Contingency	14	30	14	30	9	20	9	20	25	55	25	55	15	32	15	32
Spacecraft	**319**	**704**	**391**	**863**	**305**	**674**	**376**	**830**	**322**	**710**	**348**	**768**	**291**	**641**	**319**	**703**
Propulsion	50	110	56	122	46	101	56	122	47	104	56	122	47	104	56	122
Attitude Determination and Control	25	54	39	86	25	54	39	86	25	54	24	54	25	54	24	54
Telemetry, Tracking, and Control	11	24	11	24	11	24	11	24	11	24	11	24	11	24	11	24
Command and Data Handling	11	24	12	27	11	24	12	27	11	24	12	27	11	24	12	27
Thermal	10	22	12	26	9	19	10	23	12	27	13	28	10	21	10	22
Power	65	143	80	176	64	140	80	176	50	111	58	128	51	112	58	128
Structure	84	186	104	228	79	175	93	205	101	223	104	230	78	173	83	184
Spacecraft Contingency	64	141	78	173	61	135	75	166	64	142	70	154	58	128	64	141
Dry Mass	**425**	**937**	**497**	**1096**	**374**	**826**	**445**	**982**	**439**	**967**	**465**	**1025**	**365**	**805**	**393**	**868**
Wet Mass	**565**	**1247**	**749**	**1652**	**498**	**1097**	**670**	**1478**	**607**	**1338**	**726**	**1602**	**497**	**1097**	**603**	**1329**
Orbit Insertion Propellant	0	0	8	18	0	0	7	16	0	0	0	0	0	0	0	0
On-Orbit Propellant	140	309	243	536	123	271	217	479	168	370	261	575	132	291	209	460
Pressurant	0	1	1	2	0	1	1	1	0	1	1	2	0	1	1	1
Launch Vehicle	Delta IV M		Delta IV M (4,0)		Delta IV M		Delta IV M (4,0)		Delta IV M		Delta IV M (4,0)		Delta IV M		Delta IV M (4,0)	
PAF Mass	**113**	**250**	**113**	**250**	**25**	**55**	**113**	**250**	**113**	**250**	**113**	**250**	**113**	**250**	**113**	**250**
Total Launch Mass	**679**	**1497**	**862**	**1902**	**523**	**1152**	**784**	**1728**	**720**	**1588**	**840**	**1852**	**611**	**1347**	**716**	**1579**
Performance	1138	2509	2700	5954	1138	2509	2700	5954	1138	2509	2700	5954	1138	2509	2700	5954
Launch Mass Margin	459	1013	1838	4052	615	1357	1916	4225	345	760	1787	3941	490	1081	1947	4293
Spacecraft (S/C) per Launch	1		1		1		1		1		1		1		1	
Launch Vehicle (LV) Percent Margin	40.4%		68.1%		54.1%		71.0%		30.3%		66.2%		43.1%		72.1%	

Adapted from SMC/XRD “PASEP” study, 2006-2008

DECISION TREE FOR GROUND-BASED RADAR



Adapted from SMC/XRD "PASEP" study, 2006-2008

KEY TRADES - FREQUENCY

Parameter	X-Band	Ka Band
Transmitter Power (MW)	2.5	2.5
Aperture Area (m^2)	50	16
Beamwidth (deg X deg)	0.177 x 0.354	0.126 x 0.126
Number of Transmit/Receive (Tx/Rx) Modules	222,222	871,000
Tx/Rx Module Power (W)	10	3.5
Power Density (kw/m^2)	50	156
Availability		At least 10 dB more attenuation in clouds, fog, and rain
Cost	$x	> $4x

Adapted from SMC/XRD “PASEP” study, 2006-2008

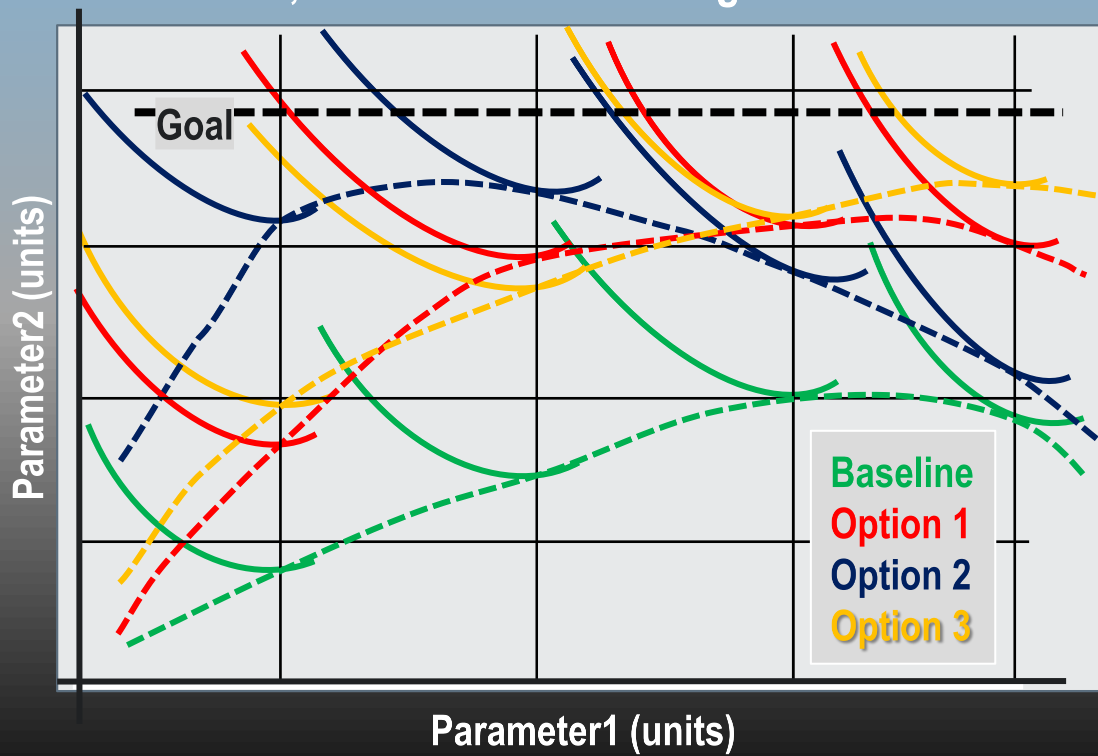
KEY TRADES - ANTENNA TYPE

Parameter	Phased Array	Gimbaled Dish
Weight	Less structural metal, no gimbals Future improvements in Tx/Rx module packaging and power efficiency will reduce weight	
Volume	Generally less than dish and gimbals	Less signal processing equipment
RF Losses	Future improvements in materials and packaging will reduce losses Cryogenic cooling can help reduce losses	Lower losses due to no need for element combining networks
Tracking	Tracking speed set by computational speed Parallel processing and combining multiple digital signal channels allow simultaneous tracking of multiple targets	Tracking speed set by mechanical scan rate
Power	Tx/Rx modules produce ~10W each at X-band	For similar aperture size, transmit power is greater than PA antenna
Gain	Loses effective area due to gaps/edges between elements	Loses effective area due to blockage by feed
Sensitivity	Large number of elements enables advanced adaptive processing	
Cost	High cost of Tx/Rx modules (NOTE: DARPA research projecting unit cost decrease from ~$100 to ~$10 over next 10 years)	

Adapted from SMC/XRD "PASEP" study, 2006-2008

THE CONUNDRUM – WHEN SHOULD I MAKE THE DECISION? (or "How Much Data Is Enough?")

- Excessive short-term **cost consciousness** (or "affordability-awareness"; the situation is not unique to DoD, though) leads to corporate **reluctance to commit resources**
- **An option that looks promising at one point in time may look less so later**
- A **risk-averse decision environment** often means no decision at all: advocates have to bring a case that is technically and statistically sound, complete, current, relevant, rational, etc. in terms of making the case for investment



TOP 10 DA CONSIDERATIONS THROUGHOUT THE LIFE CYCLE

- **UNIVERSAL**
  - Applies to all domains, industries, product areas, research areas …
  - One size (policy, process, procedure, prior idea …) seldom fits all

- **COLLABORATIVE**
  - Understand the realities of -- and constraints imposed by -- external factors and influences (government, industry, academia)
  - The human is an external factor, and always introduces uncertainties

- **NOT FOR THE NEOPHYTE – REQUIRES MORE THAN BASIC INTELLIGENCE**
  - Know what you want, and measure smartly … Accuracy ≠ Precision
  - Beware of "DRIP" -- especially in response to requests for Rocks

- **RESPONSIVE, BUT REALISTIC**
  - Customers often press for immediate solutions over rigorous process
  - "Then a miracle occurs" should NEVER be an acquisition or transition strategy

- **ALL ABOUT SMART CHOICES**
  - Early decomposition / allocation decisions (*i.e.*, focus on either hardware or software first) are a huge driver in defining the rest of the solution trade space
  - Do it right, do it early; do it early, do it right: Decision Analysis and Decision Support Information represent Systems Thinking – to be supplemented by Systems Engineering

WHY IT'S IMPORTANT – KEY DoD ISSUES

- **Myriad external influences**
  - Dynamic global adversaries and threats
  - National fiscal imbalance
  - Increased Congressional oversight
  - Politically-driven climate
- **Hard to shift long-standing cultural paradigms**
  - Resistance (or unwillingness, or inability) to commit to prioritizing resources by capability
  - Resistance to cross-service resourcing
  - Continued focus on large platforms and systems
  - Reactive decision environment
- **Theoretical, more than practical / realistic, understanding of what is needed for comprehensive planning / management of complex systems and systems of systems**
  - Networks, service-oriented architectures (SOA), enterprise systems; emergent behaviors; etc.
  - Inconsistent application to programs, both within and across Services and Agencies
- **Customer / user expectations for mission success and meeting cost / schedule targets**
  - Difficult to reconcile risk-averse behavior and decisions

GLOSSARY – DECISION ANALYSIS, A TO X

- **Affordability**
  - Top dog in DoD at present; it has both a planning component (thinking about what options will best fit in the overall portfolio) and an execution component (thinking about how best to manage current contracts and resources)
- **Biases**
  - Can be imposed by analysts to scope work, or directed by decision-makers
- **Constraints**
  - Similar to biases in that they limit objectivity by including or excluding parts of the trade space
- **Dependencies**
  - Everything touches pretty much everything else; the difficulty is in figuring out which touch points merit attention at which decisions
- **Enterprise**
  - The unseen partner in everything; particularly significant in today's information-driven environment where real-time decisions rely on timely availability of accurate data
- **Feasibility**
  - "Then a miracle is going to occur and there will be a new wrinkle in the laws of physics!" isn't really a good technology maturation, acquisition, or transition strategy
- **Generalizations**
  - Taking for granted that dependencies and enablers will always be available is a recipe for failure

GLOSSARY – DECISION ANALYSIS, A TO X

- **Help**
  - "We don't have time to bring in the experts, so we'll just take our best guess!"
- **Integration**
  - Things work better together when they are designed to work together … many new efforts are actually modernizations and upgrades of legacy systems/platforms, few of which were really designed with future integration in mind
- **"Just A Little More"**
  - Trying to optimize (or enhance) one attribute of the system almost always sub-optimizes the system as a whole
- **Knowledge**
  - It's not so much "knowledge" *per se*, but rather how the knowledge base is to be established, populated, maintained, and transitioned from the first users (capability planners and concept developers) to the downstream stakeholders
- **Latency**
  - Data have a finite effective/usable life span … if you don't meet the milestone review within, say, a year after the analysis is complete, the decision-makers are likely to question whether the cost data (or the operational scenarios, vignettes, etc.) are still valid
- **Maturity**
  - How much thought went into the systems/concepts under consideration? Can the analysts (to say nothing of the decision makers) make "apples-to-apples" comparisons with respect to key attributes? Is any concept just a couple of PowerPoint slides and a back-of-a napkin sketch?

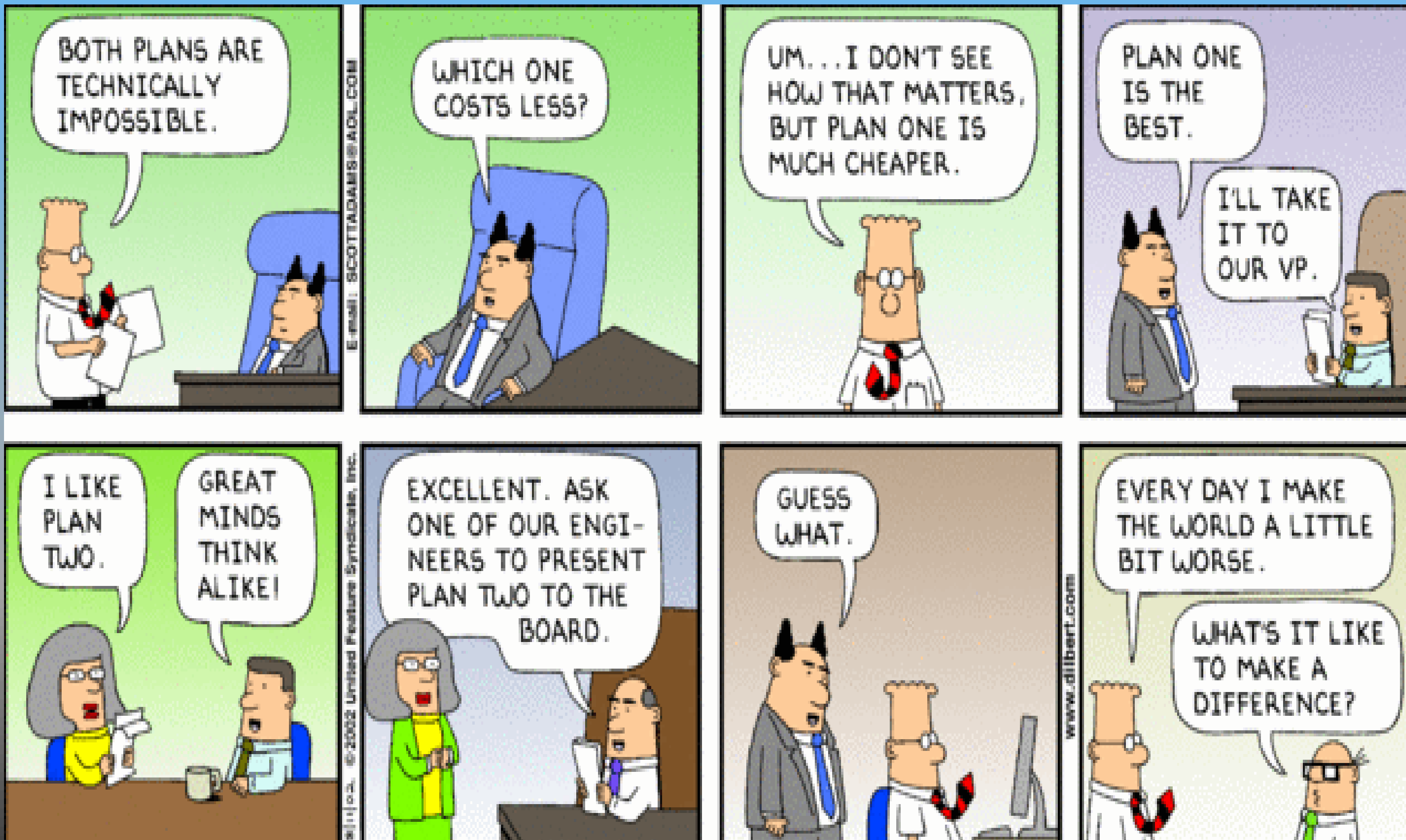
GLOSSARY – DECISION ANALYSIS, A TO X

- **Novelty**
  - It's okay – in fact, it's probably a really good idea – to think "outside the box" (especially in emerging realms such as cyber)
- **Operational Context and Operating Concept**
  - Similar-sounding terms, but very different things: Context is more about the environment in which the system will exist and operate; concept is more about what the user expects to do with the system, and how it will benefit the ability to accomplish missions and objectives
- **Pressure**
  - Comes in many different forms; one of the most common is the customer/user clamoring for something to improve operational capabilities ASAP; other sources are availability or unavailability of resources (*e.g.*, money, people, range time, etc.), the political environment, the promotion/PCS cycle, etc.
- **Quick**
  - Moore's Law – computing power doubles approximately every 18 months – still applies to IT, and more so to cyber; cyber adversaries are exceptionally versatile, agile, and innovative
- **Reusability**
  - Options to reconfigure, reallocate, or re-engineer need to receive objective consideration if they make technical, technological, and economic sense
- **System-of-Systems Awareness**
  - Very little gets done by a "one-of" product/system/platform/asset – or individual

GLOSSARY – DECISION ANALYSIS, A TO X

- **Transition**
  - What if any thought has been given to moving to the next step or steps? This applies to both life cycle phases and process steps, and to elements of the knowledge base
- **Unanticipated Consequences**
  - Nothing is EVER going to be perfect, and nobody is 100% prescient in guessing how the future will look … some implications of tomorrow's decisions might not bubble to the surface for 10 or 15 years; some of those may validate today's assumptions, and some may cause people to wonder what we were thinking when we made those decisions
- **Value Added**
  - Did the information contribute to the discussion and the decision? Or was the outcome pretty much a foregone conclusion?
- **"What-If?"**
  - Sensitivity analysis is an important part of a decision support information package (of course, it helps to know what factors the decision-makers consider most significant; see "Biases" and "Constraints" above)
- **X**
  - The ever-present unknown – but not necessarily a bad thing, as long as the analysts and the decision makers are aware that it exists, and as long as the information identifies it as such; early technical planning should convert "Unknown Unknowns" into "Known Unknowns"

Not Everything Is In Your Control



"We demand rigidly defined areas of doubt and uncertainty!"

Douglas Adams,
The Hitchhiker's Guide to the Galaxy

http://www.noao.edu/image_gallery/images/d3/02676a.jpg