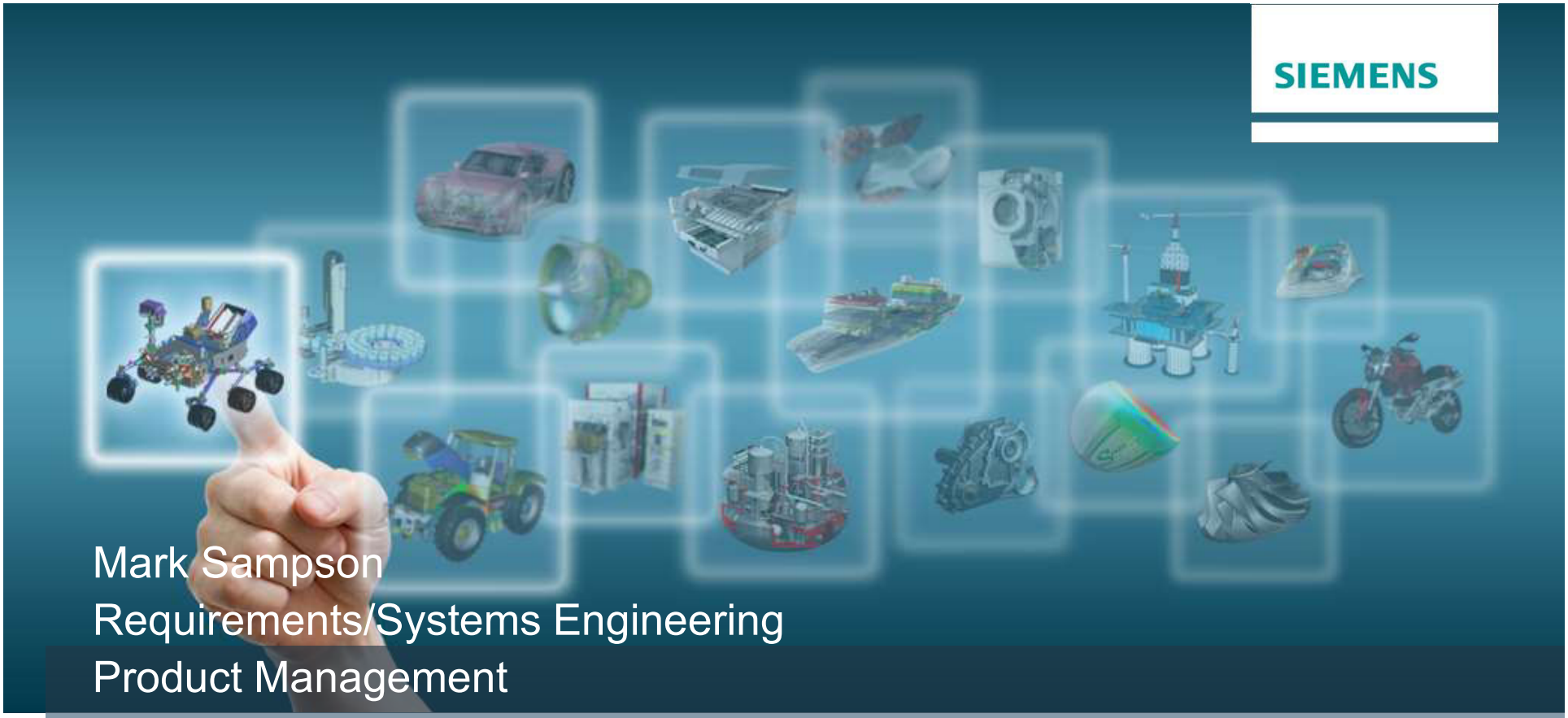

Mark Sampson
Requirements/Systems Engineering
Product Management

Integrated Systems Engineering Managing Complexity

Apollo Moon rockets vs. Greeting Cards
Accelerating complexity…

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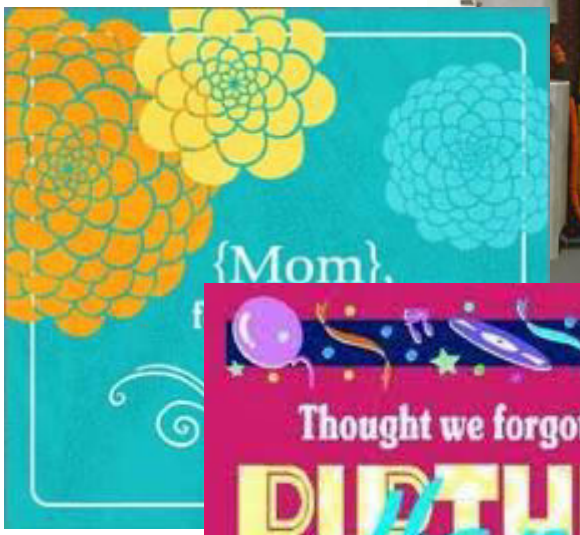
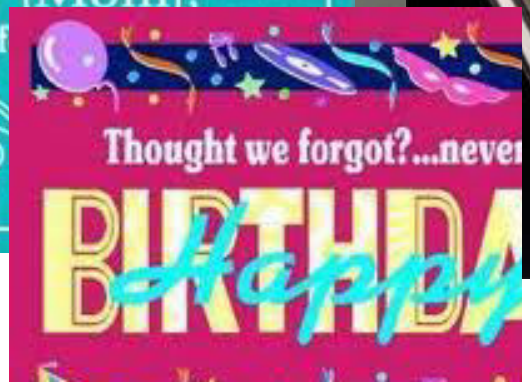
Apollo Guidance Computer (1966)

- 1st IC-based computer
- 2k core, 36k ‘rope’ memory
- 11.72 micro-second cycle
- 55 Watts
- 70 lbs
- 24” x 12.5” x 6.5”
- $$$$$$$$

Hallmark Card (today)

- 256mb+ memory
- ~2 ghz
- 1900 mAh (2 yrs)
- .085 oz
- 1” x 1” x .25”
- .$ <$1





Increasing complexity everywhere…

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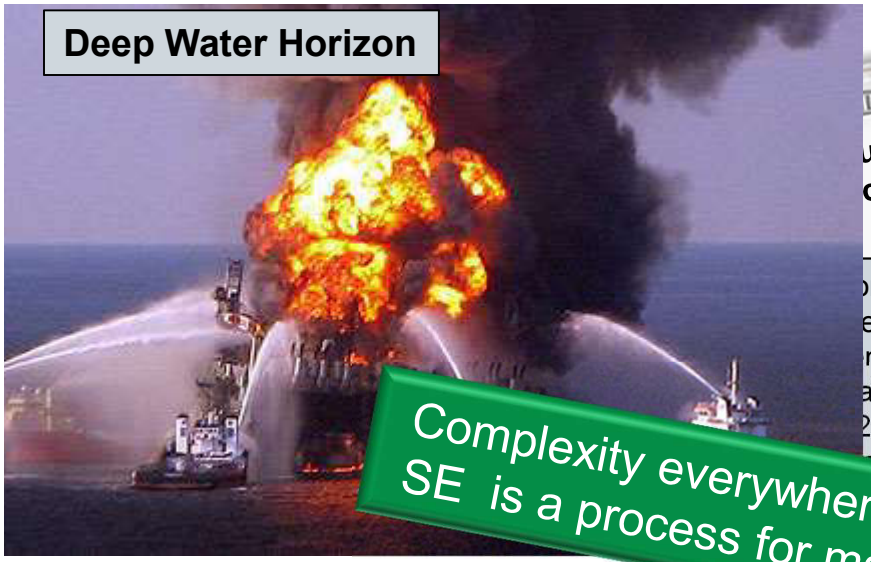
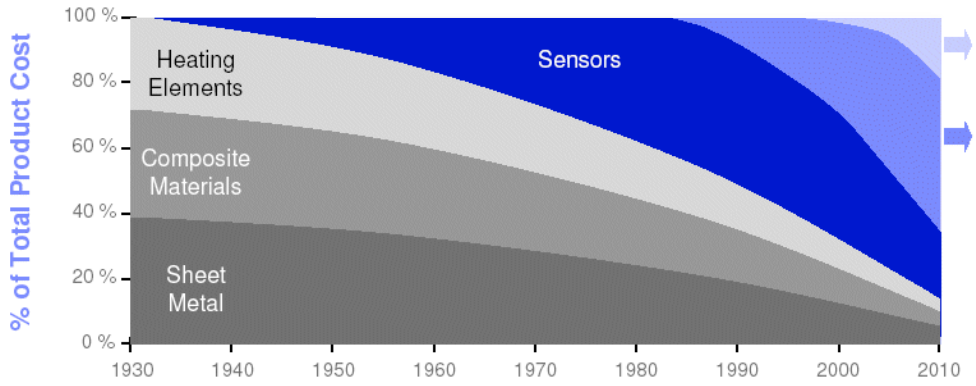
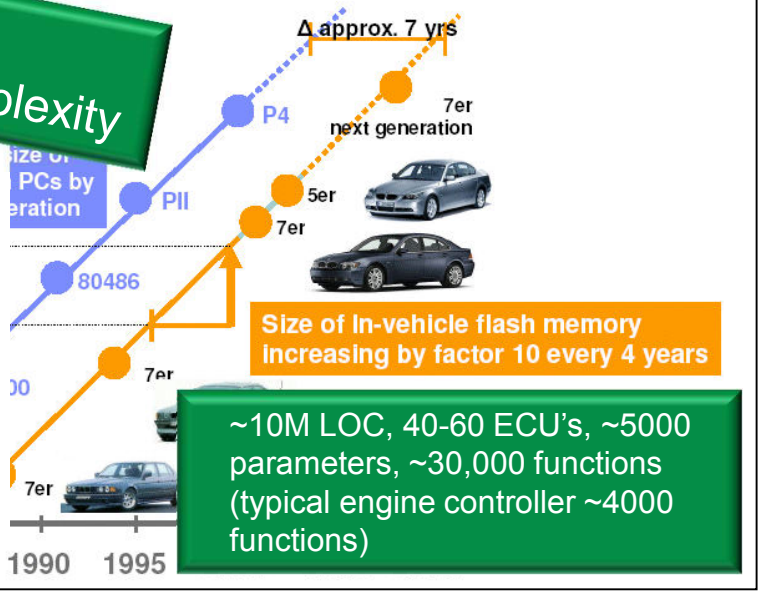


~5000 sensors, ECU's, etc. communicating over 9000 connections via 1,000,000+ types of

Complexity everywhere…
SE is a process for managing complexity

Illustrative case example: Washers & Dryers





Size of In-vehicle flash memory increasing by factor 10 every 4 years

~10M LOC, 40-60 ECU's, ~5000 parameters, ~30,000 functions (typical engine controller ~4000 functions)

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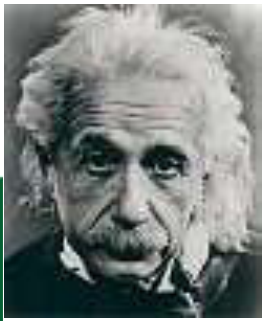
Unmanaged complexity produces problems…

- Failing to manage cross-domain interactions/interfaces show up as problems later→
- Ignoring the risk is not affordable…
- 53 million vehicle recalls in the US last year (more recalls then vehicles sold
- Each recall costs ~$100/vehicle/recall ($5.3 billion/year) in direct costs

A sample list from the NHTSA recalls database…

- …recalls 1.3 million vehicles where engine controller may develop solder joint cracks due to vibration
- …recalls 1021 vehicles with automatic rear lid with leaking gas struts could cause injury…software update
- …recalls 3.6 million vehicles…speed control switch leaks and overheats
- …recalls 10,113 vans…brake lights don't come on after first time; brake control software update.
- …recalls 437 vehicles…seat sensor calibration error doesn't turn on air bags

The significant problems we face cannot be solved at the same level of thinking we were at when we created them.



Albert Einstein

[http://www.nhtsa.gov]

Challenges in the “New Normal”
Success is getting harder

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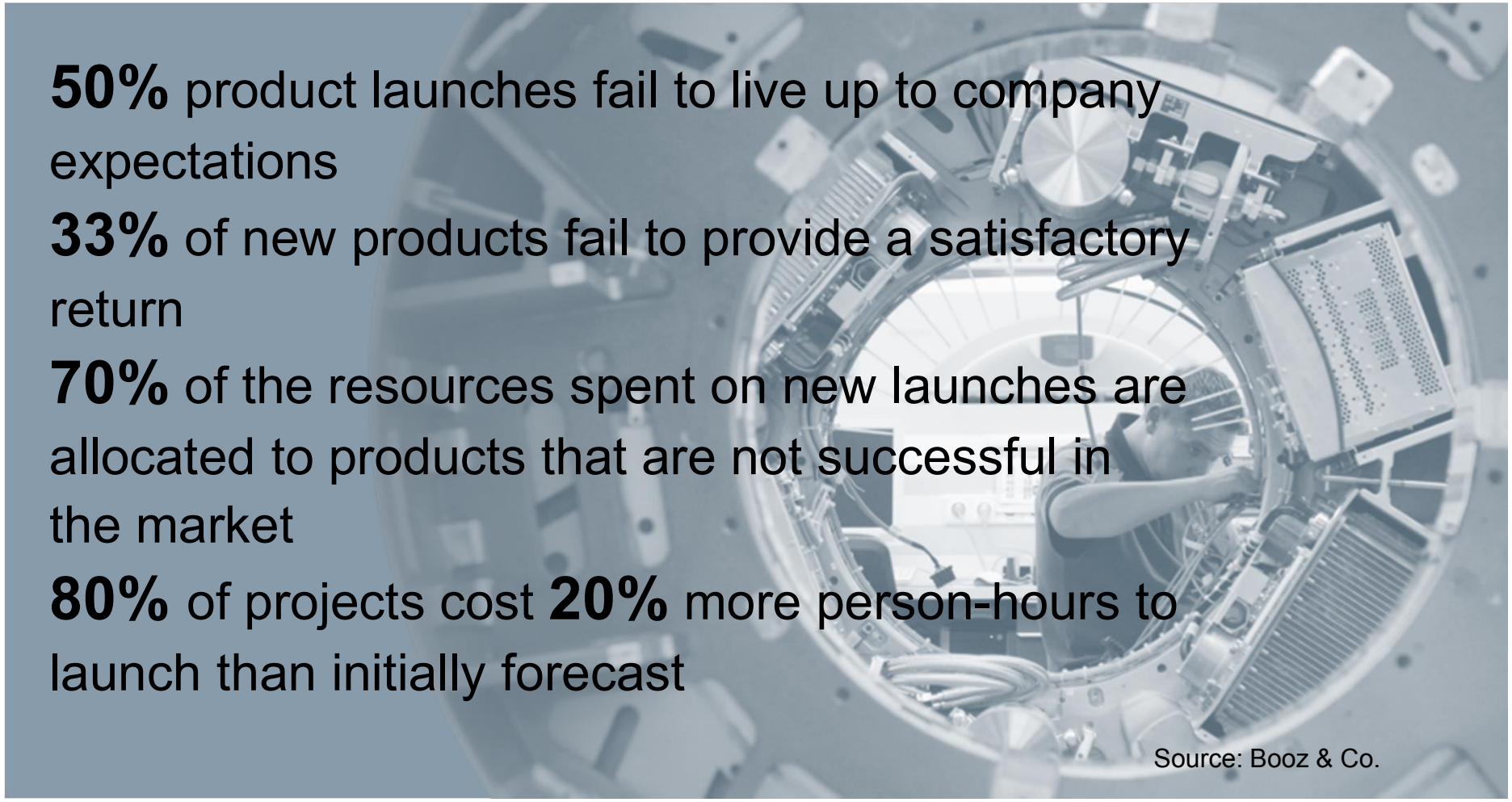

50% product launches fail to live up to company expectations

33% of new products fail to provide a satisfactory return

70% of the resources spent on new launches are allocated to products that are not successful in the market

80% of projects cost **20%** more person-hours to launch than initially forecast

Source: Booz & Co.

The systems engineering process to handle complexity EIA-632, IEEE 1220, ISO 15288,...

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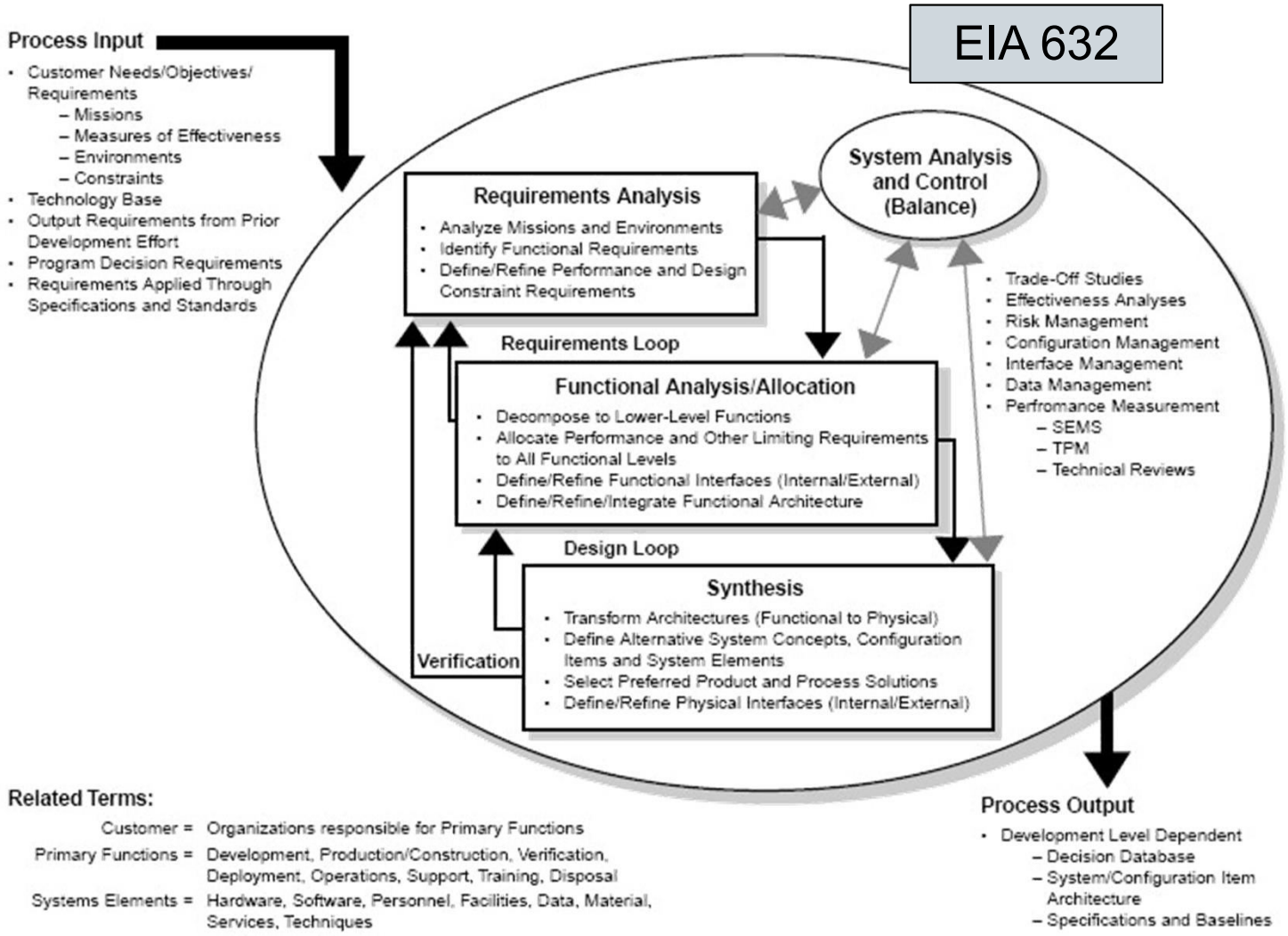
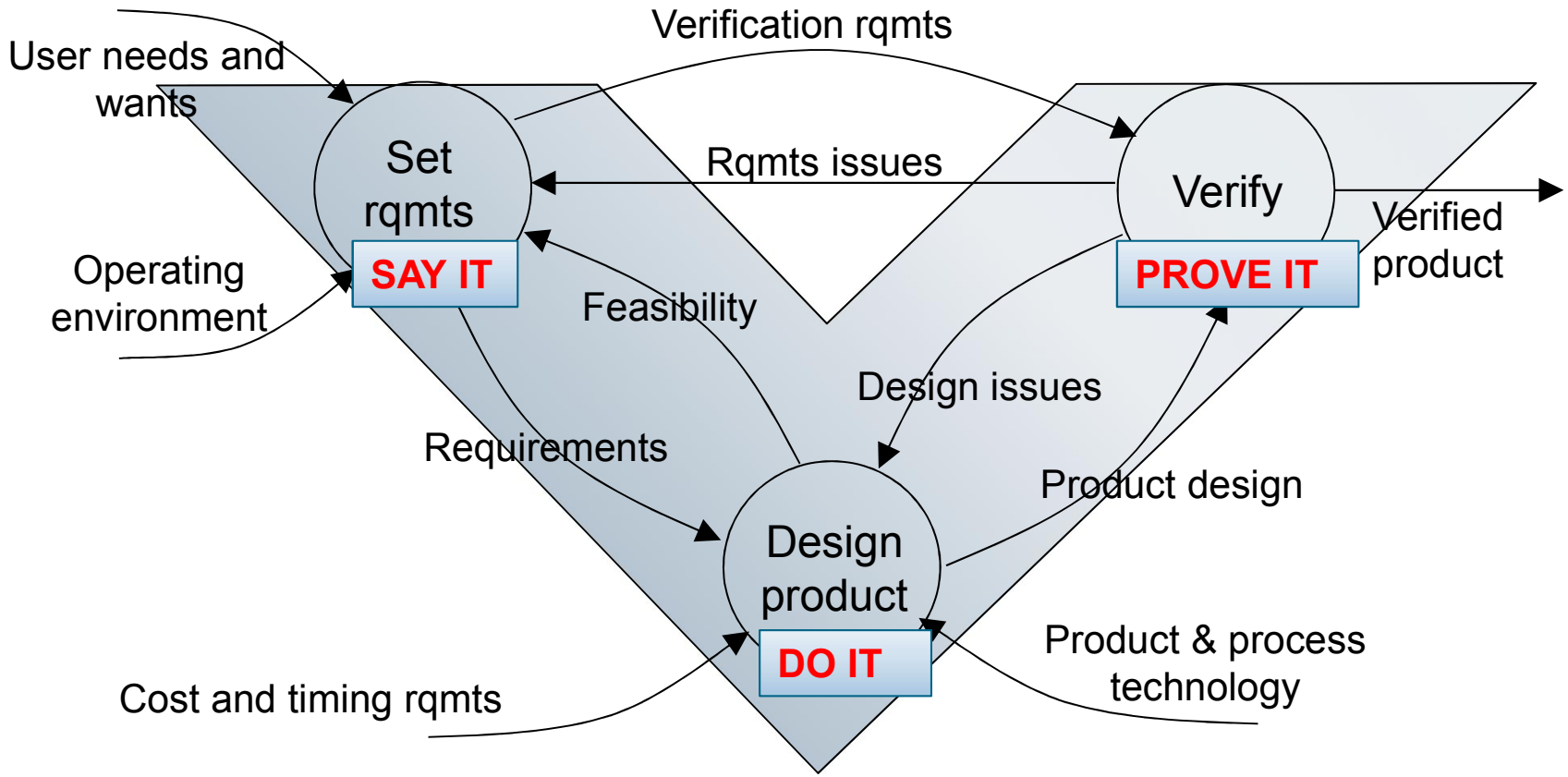
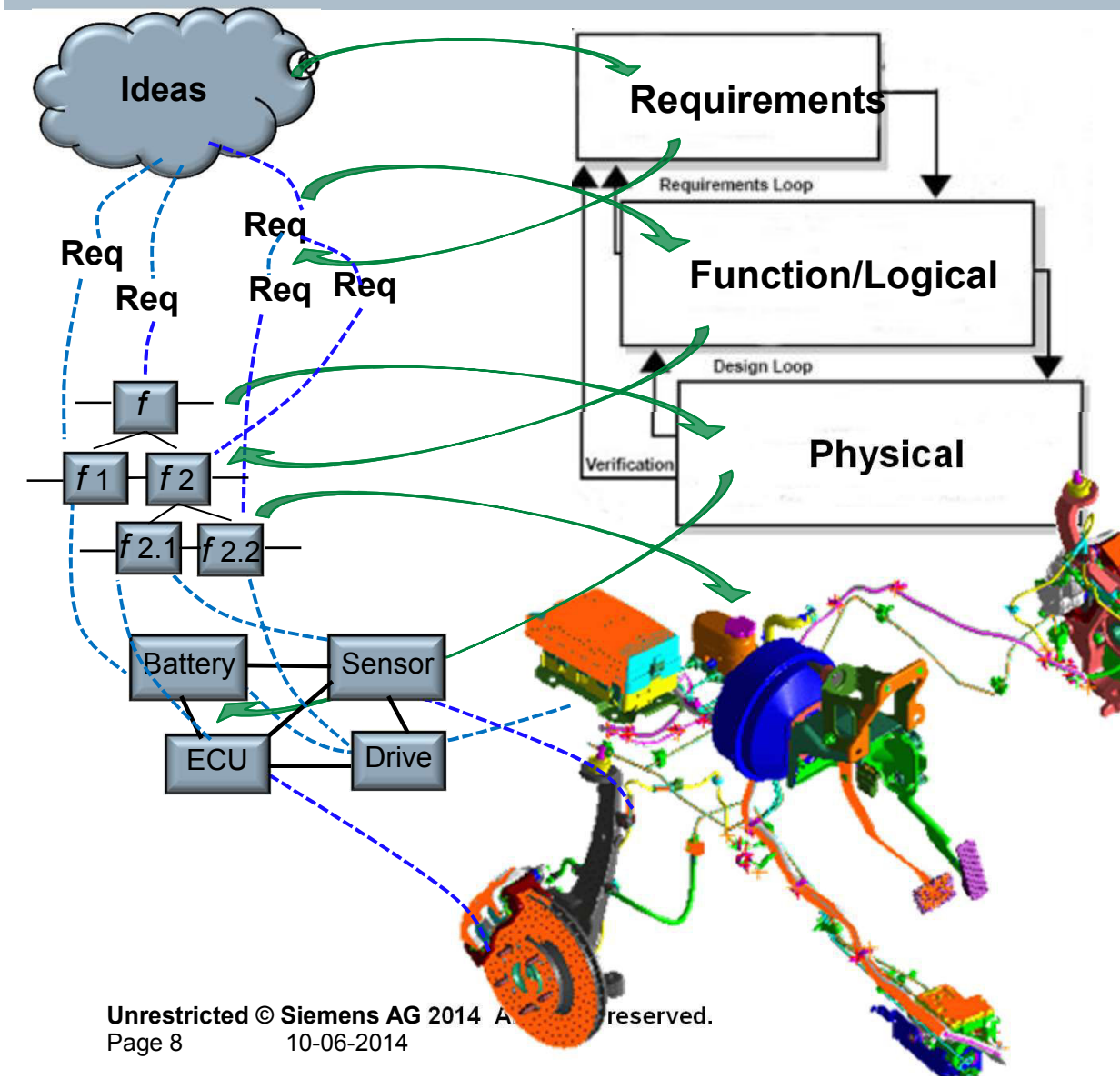


Systems Engineering/Requirements process…



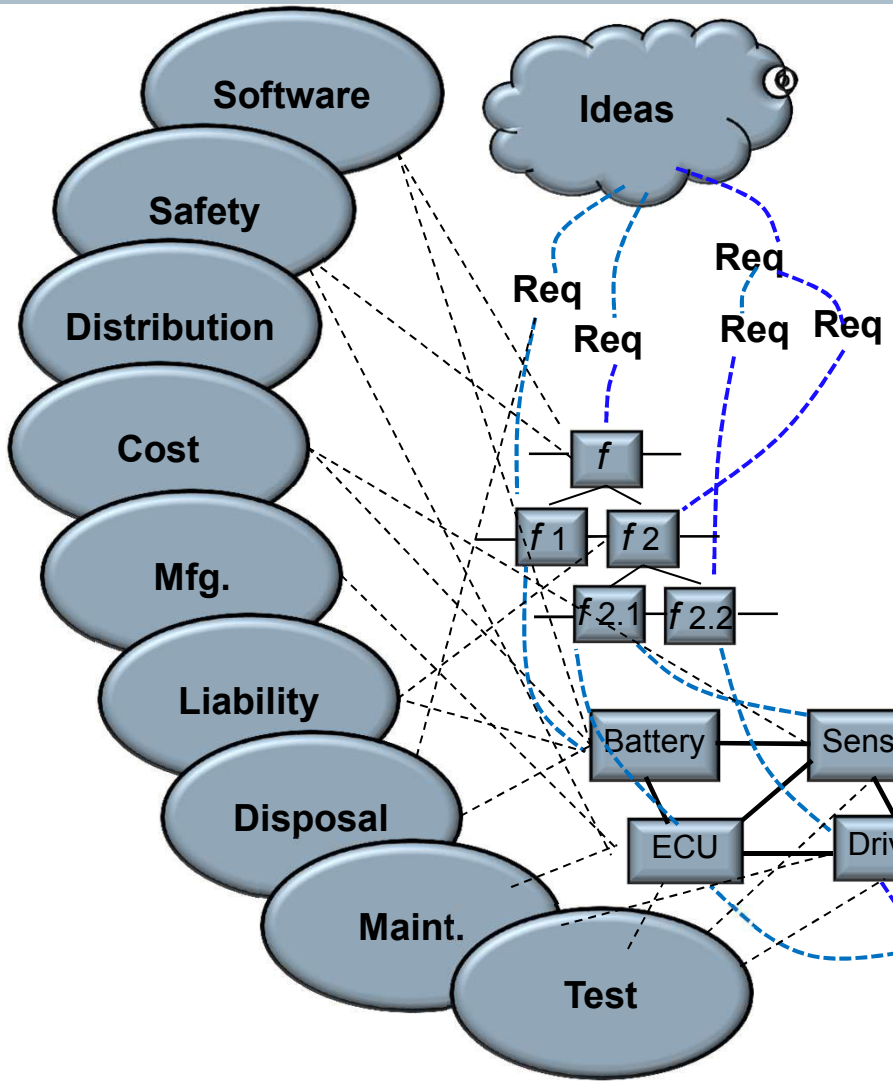
The Systems Engineering Process…



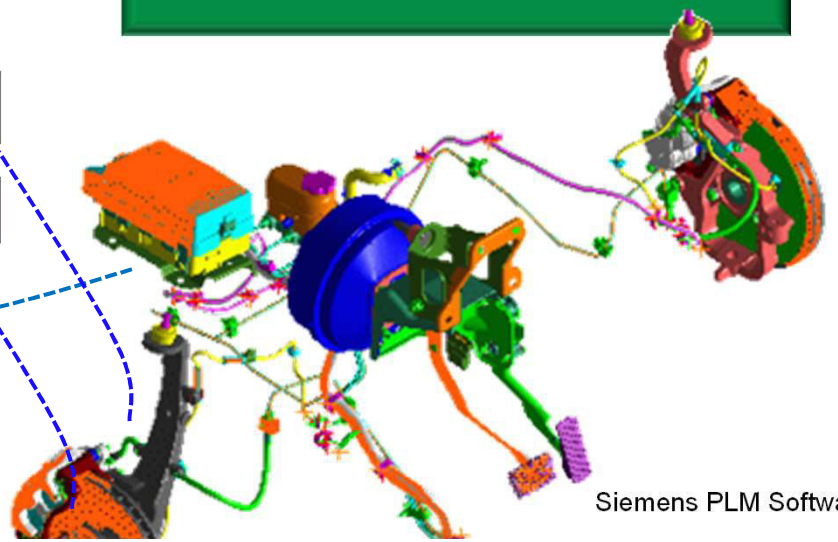
- FRAT (Commercial) vs RFAT (Mil/Aero, Energy,…)
- Captured requirements…
- Linking requirements to functions…
- Functions linked to physical alternatives…

…keep going until realizable

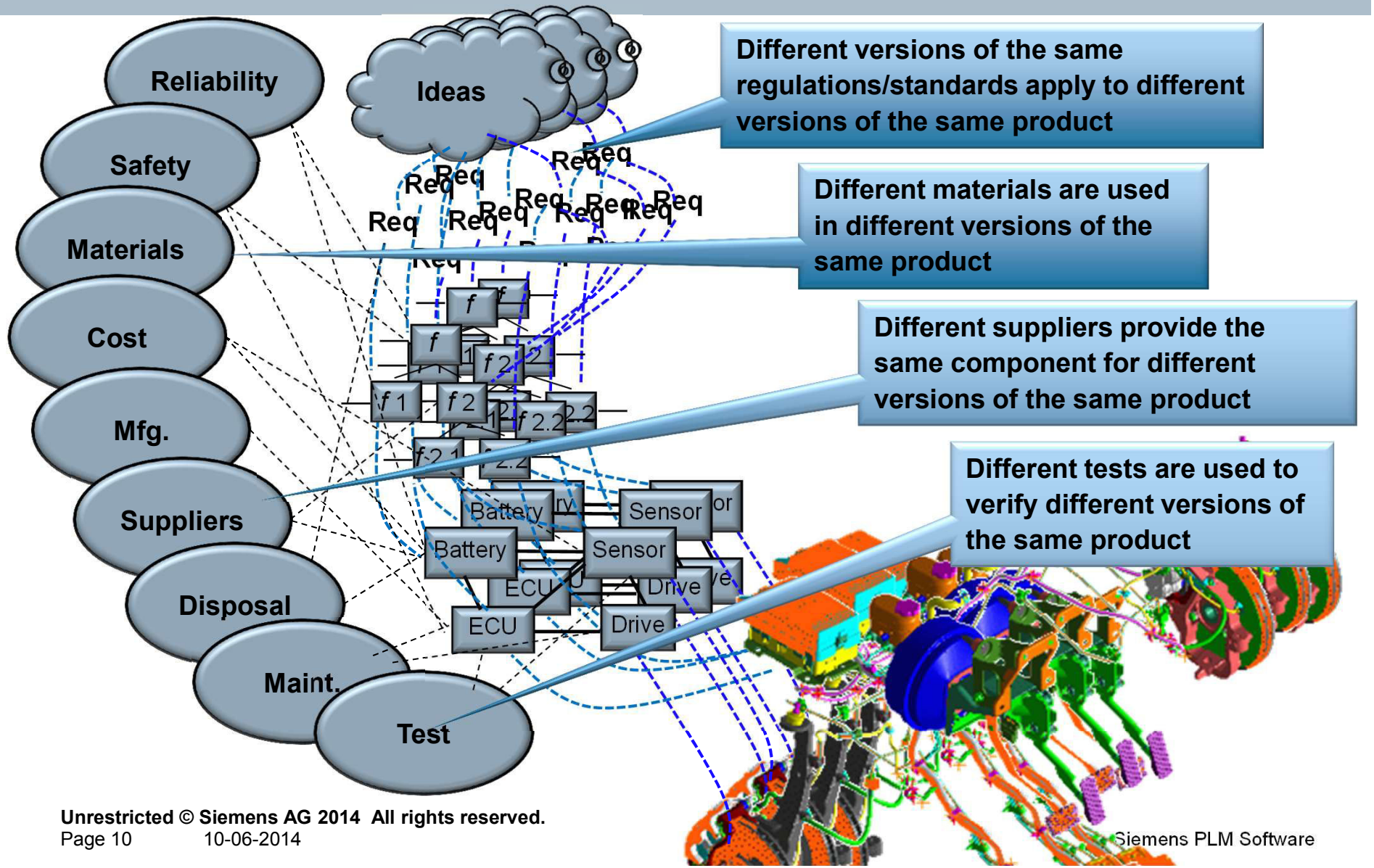
More than RFLP to worry about…



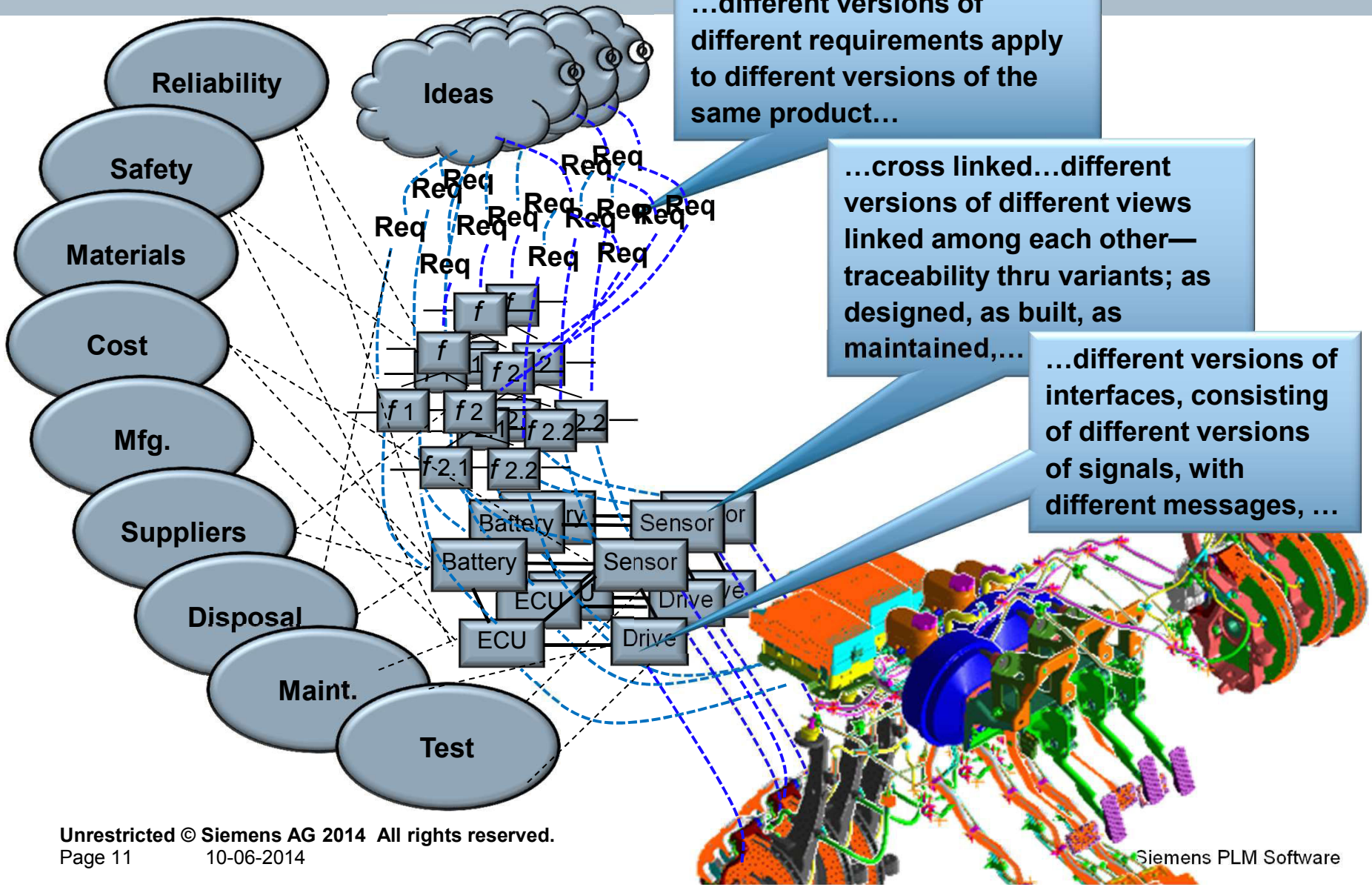
- More to a product's life than RFLP…
- No decision is an island
- Need to worry about other views (safety, mfg, cost, test, disposal, maintenance,…)
- Balance product performance against other views to achieve "global optimization"



…managing change and variation



…changing over time[10]



SE/RM needs to be integrated with PLM…
Up the 'what if' rate

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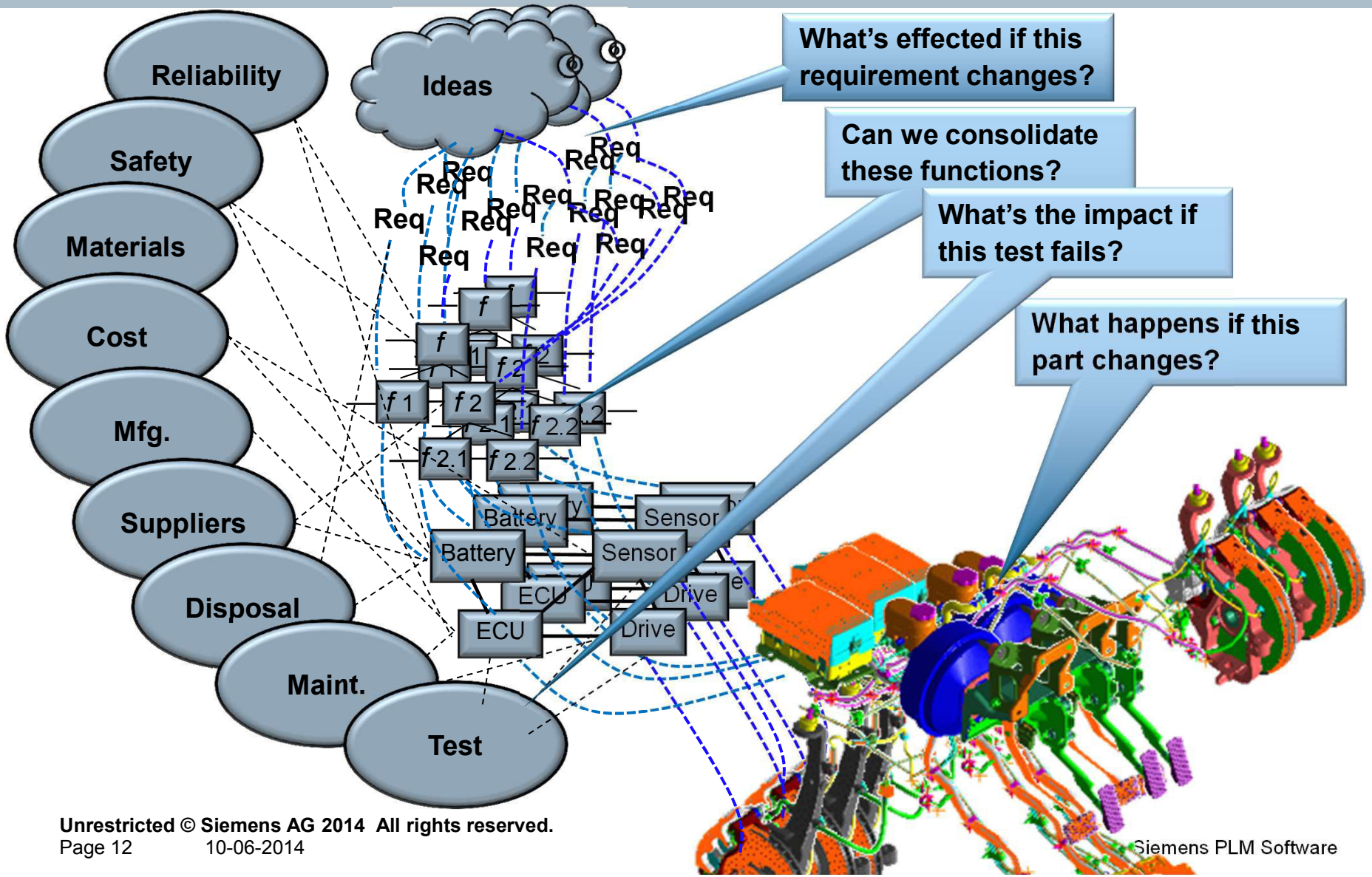
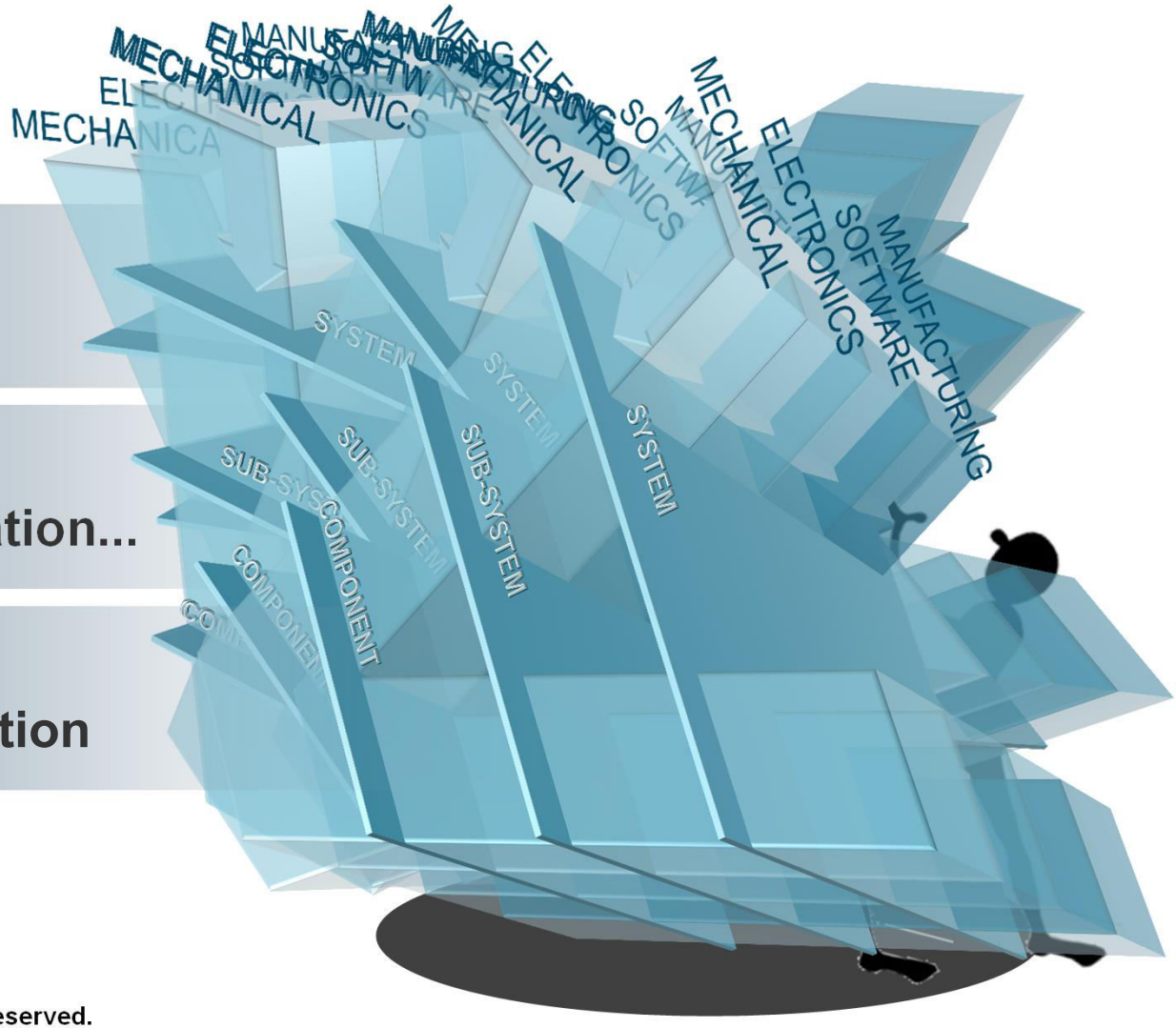


Losing your balance in the 'V'…

Multiple Simultaneous V's

Requiring multi-disciplinary coordination...

Open-loop performance verification



Complex product development success requires a balanced approach…

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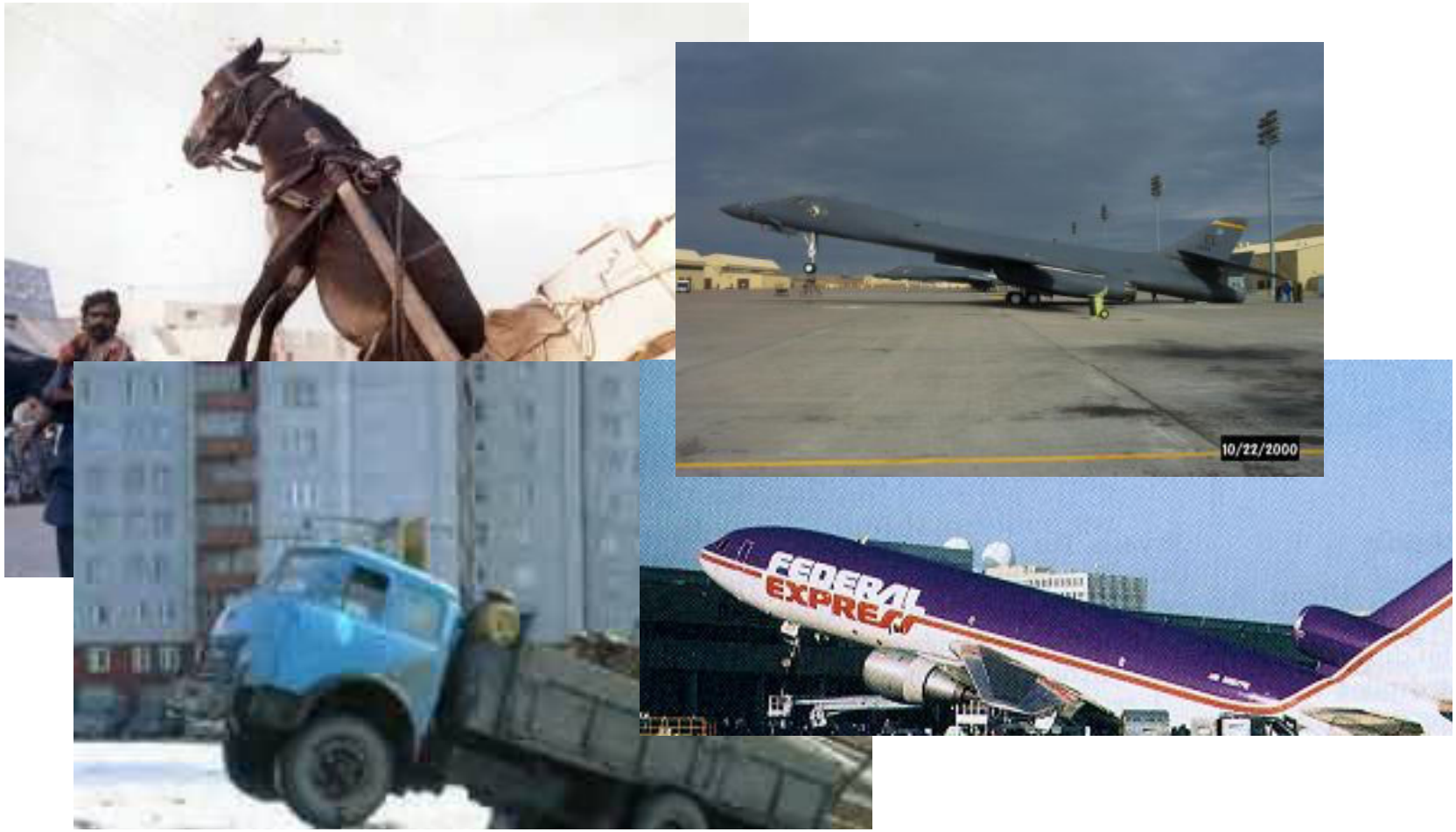

RFLP5 – Beyond Just Requirements
System Driven Product Development (SDPD)

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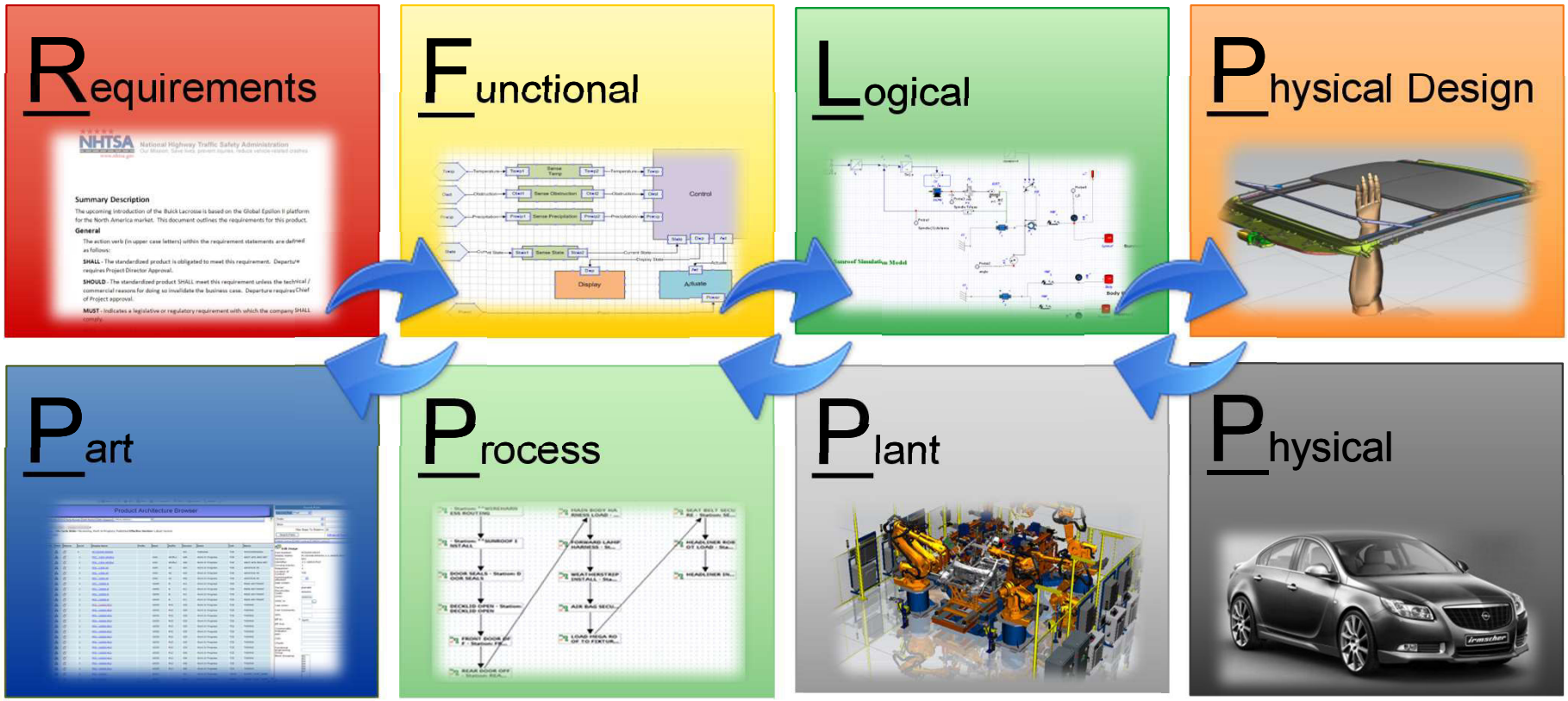
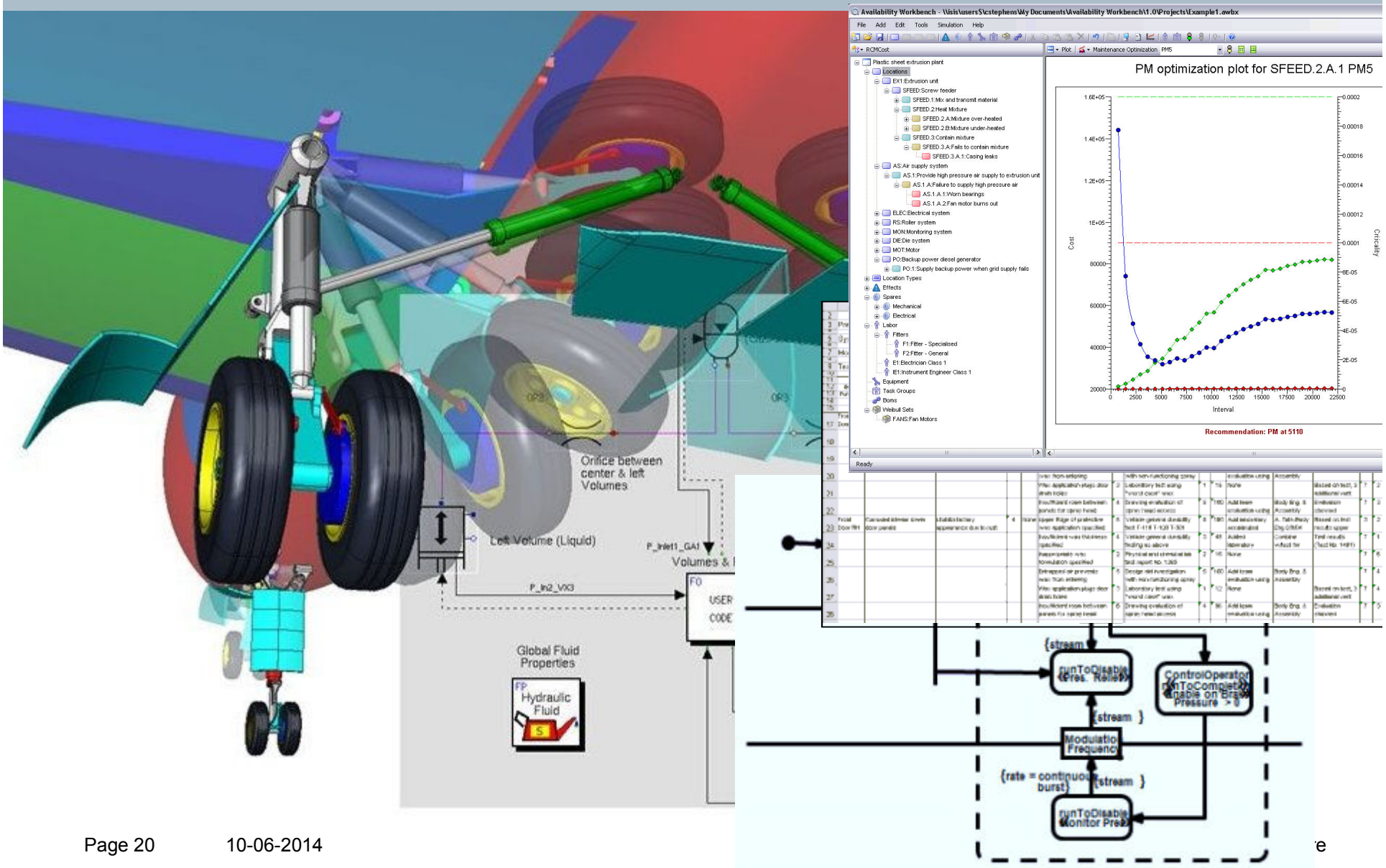
What is needed | What has to be done | How it is done | How it is implemented



Globalization, Configuration, Regulatory, and Cost brings more complexity

To achieve SDPD…
Vision: Cross-domain optimization



Where we are…
Model Configuration/Variant Management

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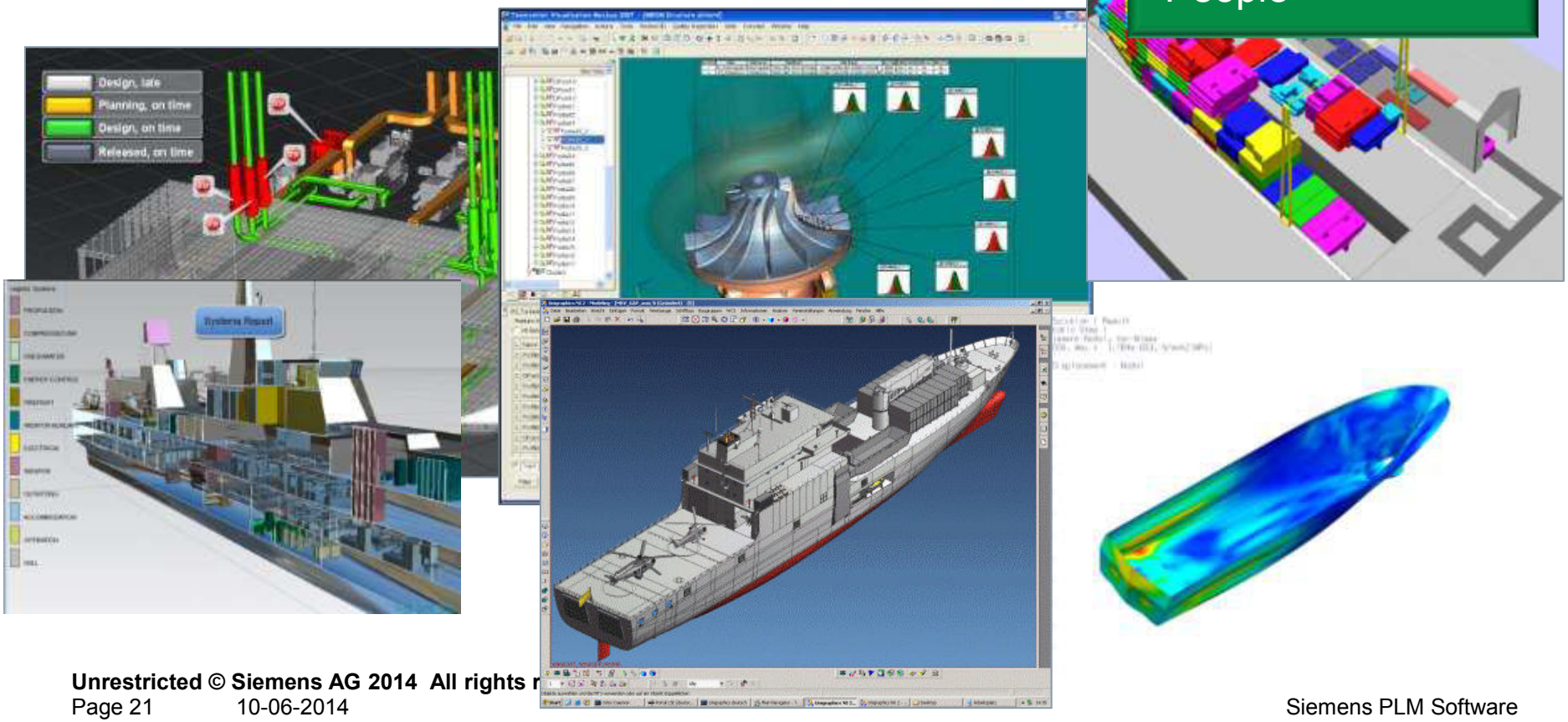
- Models associated with product elements (BOM's)
- Models configured with product structures
- Scalable to massive systems/systems of systems

Millions of parts
1000's of versions
100's of Workflows
100's – 10,000's of People



Where are we…
Requirements moving between physical, mfg, project, ... models

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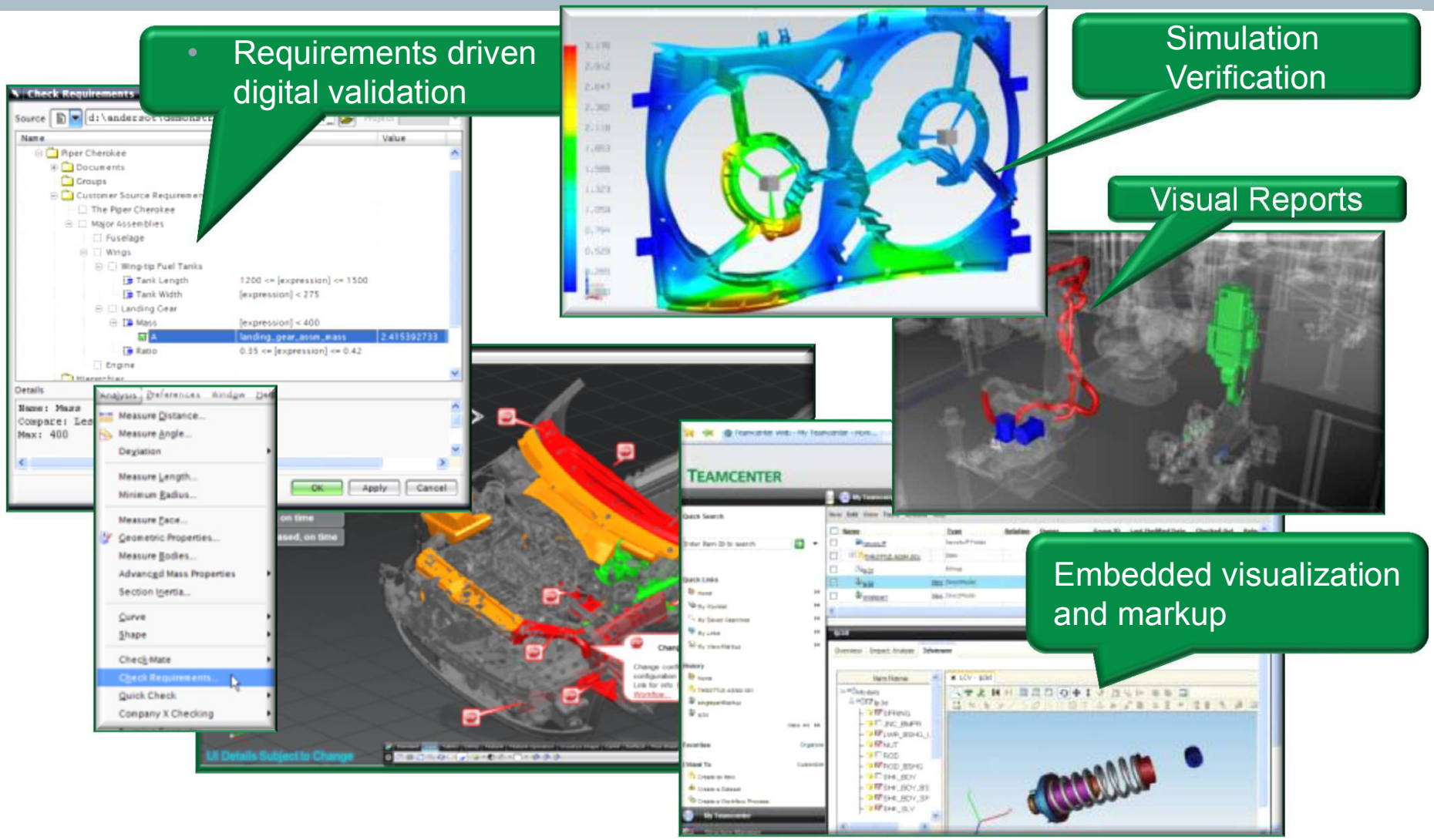

Systems Engineering
Value of SDPD/Integrate Product Architecture capture/delivery

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"All the really bad mistakes are made the very first day of the program"

-Simon Ramo

Benefit of integrated systems engineering:

- Robust/Sustainable product architectures
- Trace across domains, lifecycles,…
- Synchronize cross-disciplinary, global teams
- Maximize design re-use
- Drive real-time system-level validation

Drive systems engineering/product architecture thru-out the lifecycle starting before product design work begins

Utilizing standard systems engineering UI's to capture/manipulate integrated systems models (SysML, math, behavior, reliability, safety, cost, disposal, etc.)

Managing/Delivering models across the lifecycle …integrating SE/product architecture into the lifecycle

Product Slum Insurance

Ad hoc product architecture vs. systems engineered product architecture…

Where would you rather live?

Cost avoidance…
Earlier the better

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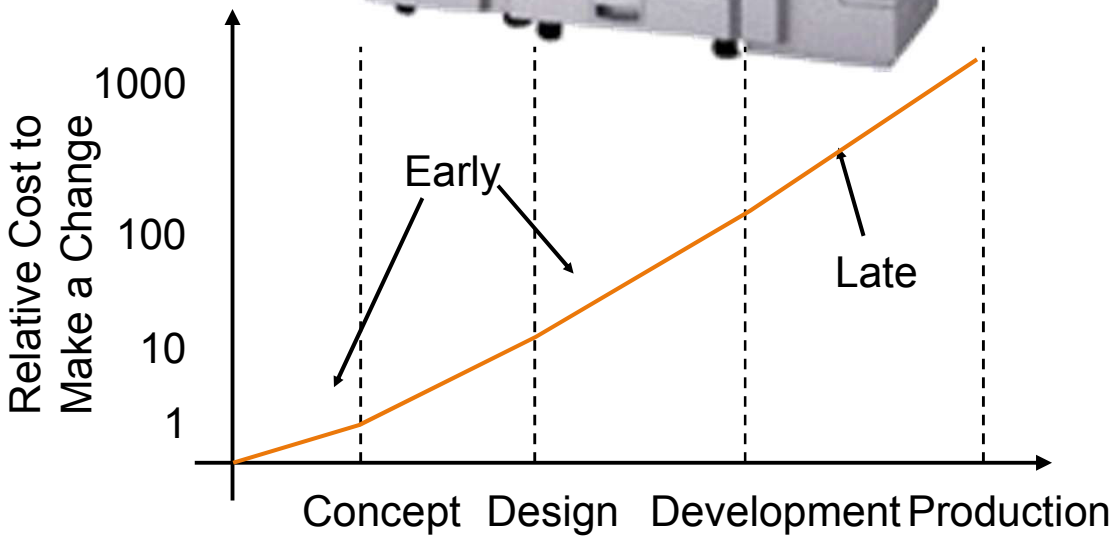
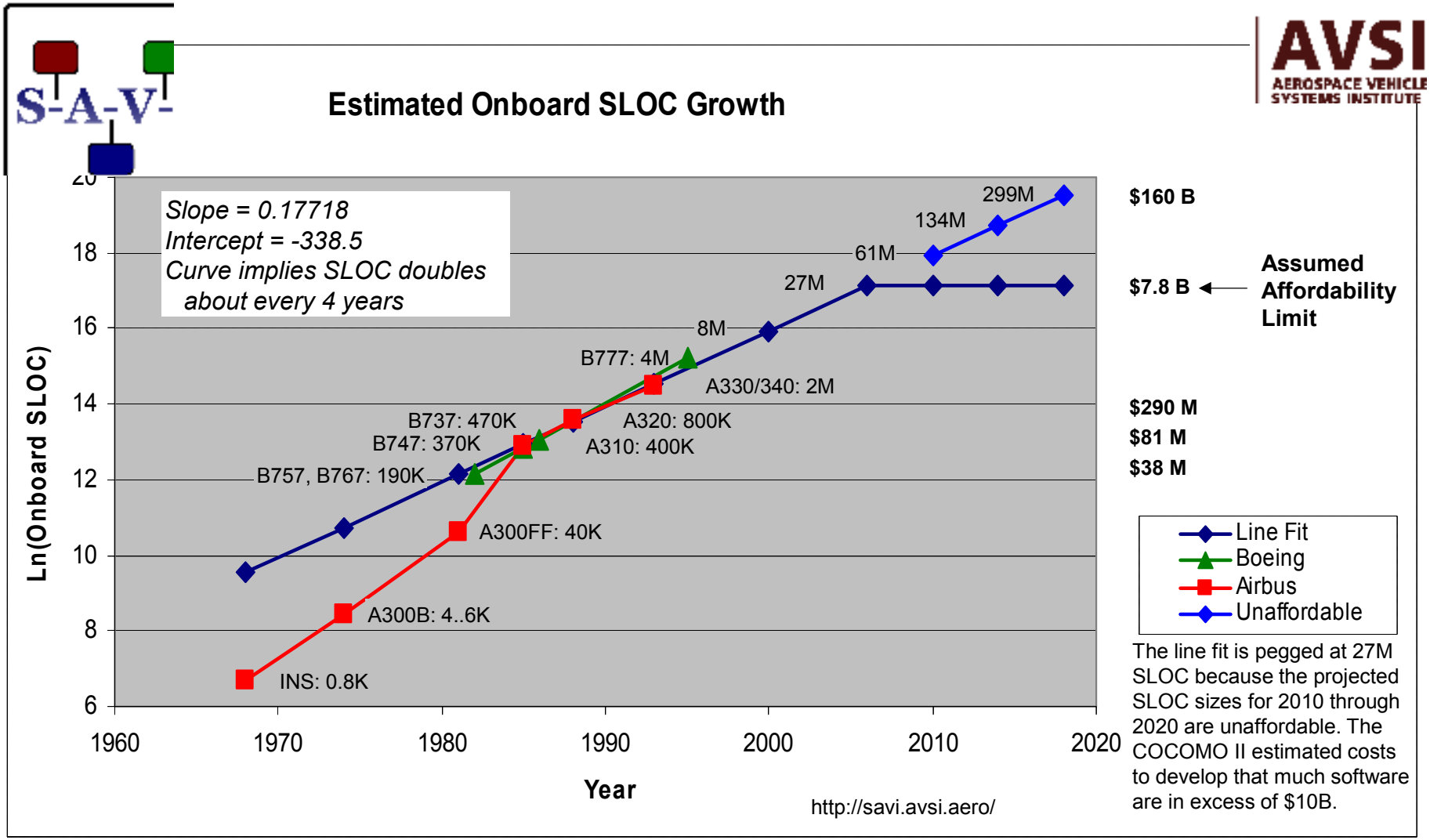
…did not find a problem with one of their copy machines until the copiers were in the field.
They quantified the cost:

- $ 590,000 for field upgrades
- $ 368 if caught before production
- $ 177 before parts procurement
- $ 35 corrected during design



“Design in” compliance early when costs are low

Complexity is accelerating…



Is it worth the trip?
The justifications don't really matter…

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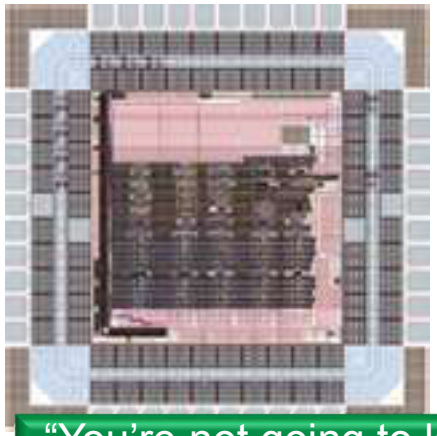
- Complex systems are everywhere…
- Murphy laws: Bad things will happen if left unmanaged. Failures are expensive
- They require systems/cross-domain thinking to be successful
- Document-based processes are not scalable to the complexity, magnitude,..
- Integrated/Automated Systems thinking is required



"You're not going to lay out a billion-gate integrated circuit by hand in your life-time"

Dr. Charles Rose at TI
(Inventor of HDL's)

"…no two BMW 5 series sold last year were the same. "

~5000 sensors, ECU's, etc. communicating over 9000 connections via 1,000,000+ types of messages, performing 2000+ functions in triple-redundant, physically separated fashion with each tail number a different configuration

This requires change…
High-tech experience

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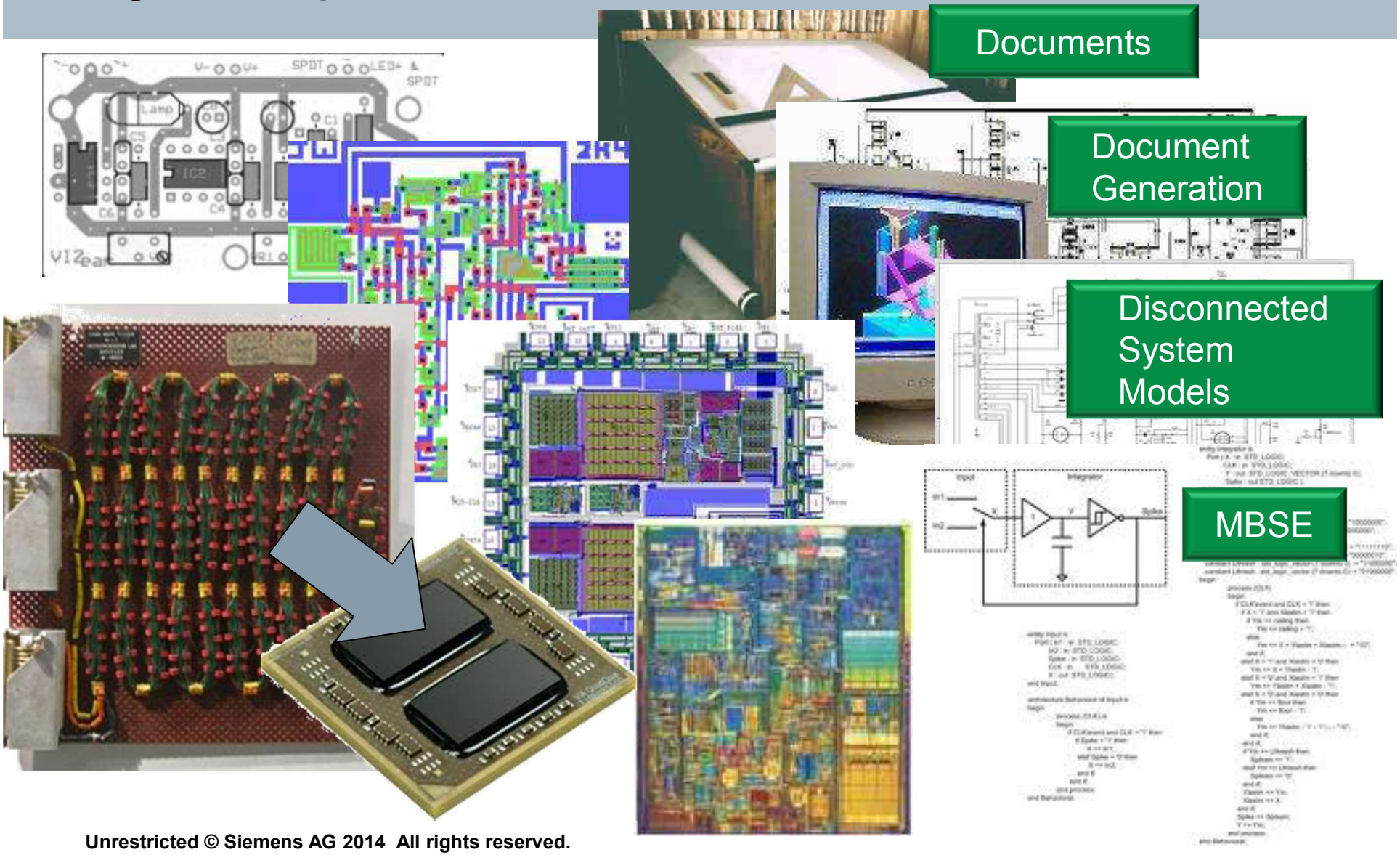

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Teamcenter

Enterprise Requirements Management
Enterprise Systems Engineering

Thank You

Applying systems engineering to deploying SE tools

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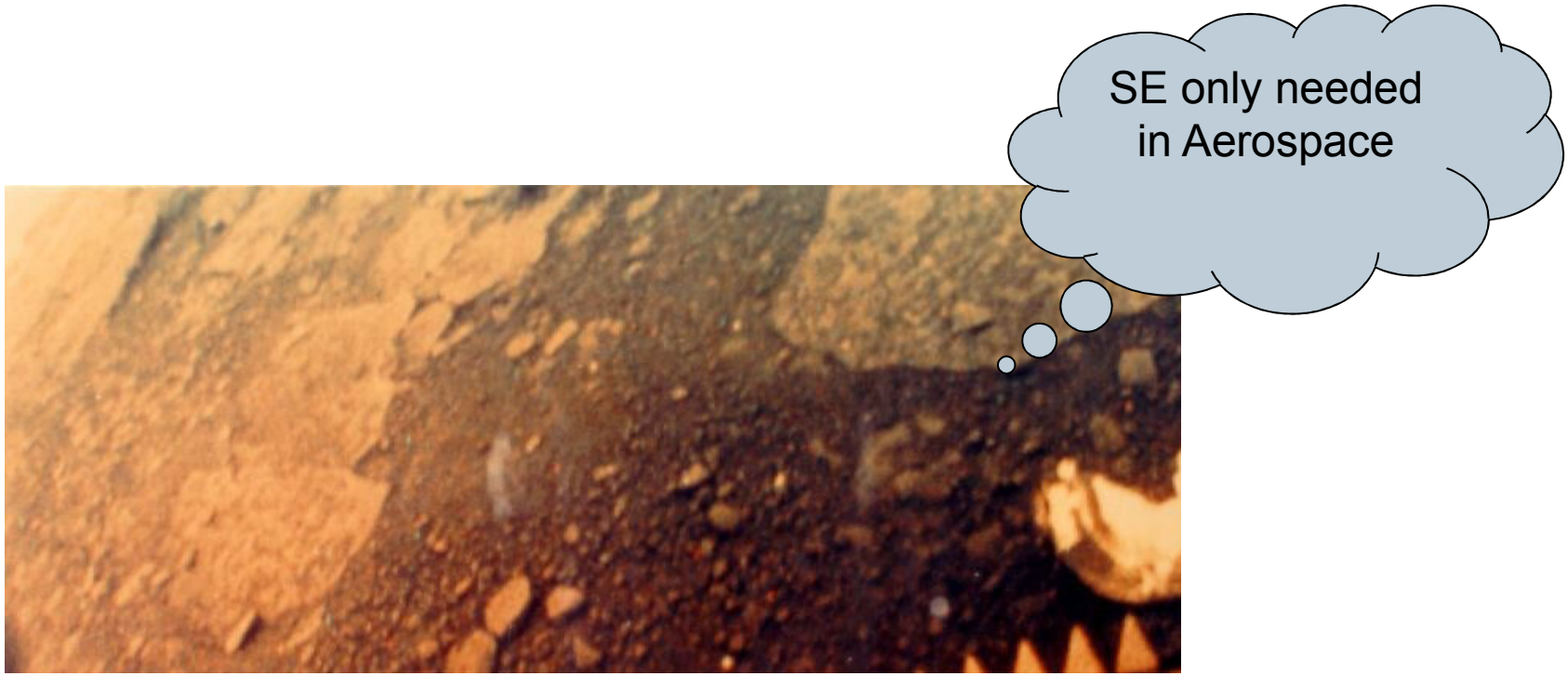

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Dishonesty/Meta-Dishonesty

"Semmelweis Reflex"

"…to dismiss/reject out of hand any information, automatically, without thought, inspection, or experiment"

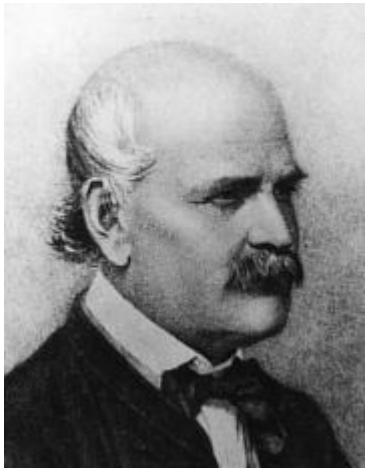
Fore-ordained answers

…will the answer provided by SE tools be accepted

Don't waste your time on the wrong answers, unless…

Dr. Ignaz Semmelweis (1818-1865)

Early Germ Theory



Wash Your Damn Hands

[http://en.wikipedia.org/wiki/Semmelweis]

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Organization Pre-prep…

Is your organization prepared to accept the answer?

"We are going on a journey.
We will carry the wounded,
but we will shoot the stragglers."

--Hallmark Cards

Management & customer backing
- Do you have time to apply the tools
- Do customers understand what you are doing

…otherwise tools are thrown overboard to get over the next schedule pass

Properly supported support organizations
- Who's going to take care of the tools?
- Who's responsible to maintain, support, answer questions about the tools

Timely Application of the tools
- SE tools are time sensitive
- Money & resources start when…

…"Catch-22" programs don't get resources until after SE decisions are made

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Organization SDB's…

- No time/money to use tools
- No backing for resources
- No training on tools
- Expecting tools to run themselves
- Thinking tools are static
- Not convincing the customer of the tool benefits
- No process for the tools to work within
- No mechanism for using tool results
- Applying the tool to everything
- Funneling everything through a gate keeper
- Expecting "paper" results from tools
- "where's the hardware?"
- Rewarding fire-fighters vs. fire-preventers
- Blockading support organizations (…they cost too much, etc.)

> …next year you will have a 90% probability of this failure…but you will do nothing about it!
>
> Dr. Stephen Wheelwright

[Covey 1995, Sampson 2000]

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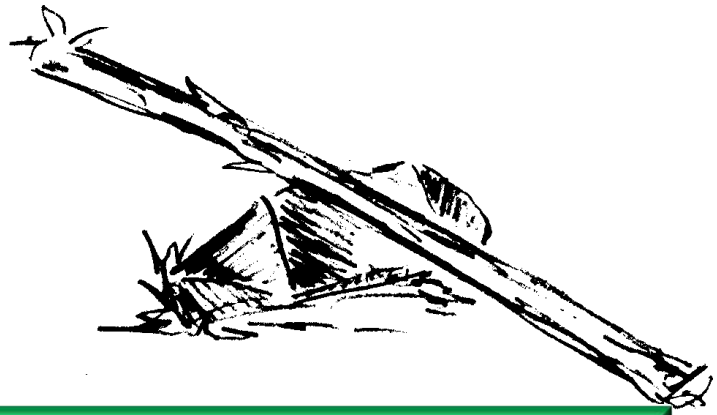
Organizational SDB's cont…

How prepared is your organization?

Culture change vs. getting lucky…



Buckminster Fuller's Magic Log

SE tool management acceptance checklist	Y	N
Did the tool support group help with the proposal?		
Has the manger forecast time & money for tool usage?		
Did the project manager help get the tools for his project?		
Has the manager forecast time & money for tool training?		
Is the manager willing to let the tools be upgraded mid project or are we stuck at this tool version?		
Is the manager willing to let his tool power users share lessons learned, be involved with user groups, etc.?		
Is the manager active in convincing his customer or the benefits of the tools?		
Are the tools used during customer reviews?		
Is there a development process being followed on the project?		
Is there a mechanism for doing something with the results of the tools?		
Is the manager involved with defining requirements?		
Does the manager see "one or two" engineers managing the product requirements?		
Does the manager have a "lets get something built" before requirements are defined mentality?		
Does the manager think the value of the tool is in its paper generation capability?		
Does he want/let the engineering automation support his project?		

[Sampson, 2000, Von Wodtke, 1993]

Cows drink…

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Cultural Considerations

After choosing the tools, convincing management/accountants to buy them, how do you get them to “stick”?

- Goal of tools to accelerate SE
- Change is required
- How to get technology/change to stick?

Rogers Technology Diffusion Theory

[Rogers, 1962]

Diffusion of Innovations…

5 characteristics of innovations that affect acceptance:

1. Relative Advantage—perceived as better
2. Compatibility—consistent with values
3. Complexity—how difficult to understand & learn
4. Trialability—experimented with
5. Observability—results visible to others

[Rogers, 1962]

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Diffusion of Innovations…

5 kinds of people in organizations…

1. Innovators (2.5%)—risk takers, information from many sources, adventure-some
2. Early-adopters (13.5%)—social leaders, popular, fast trackers
3. Early-majority (34%)—deliberate, informal social circles
4. Late-majority (34%)—skeptical, traditional,…
5. Laggards (16%)—fear of change, resistant, militant…

[Rogers, 1962; McKown 2003]

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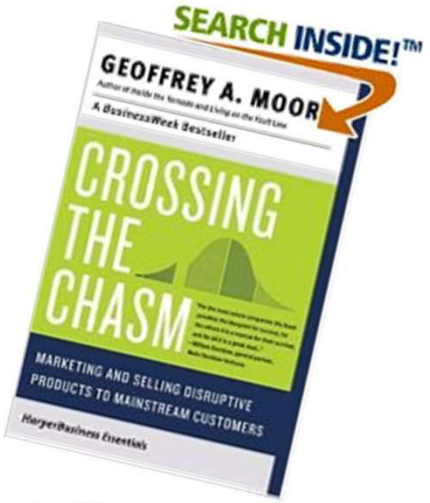
Diffusion of Innovations…

…the way people perceive an innovation matters more then the merits of the tool itself.

Rogers' Theory Suggests:

1. Start with pioneers on your first project application—innovators, anxious to make it go, and move on the to the next new thing
2. Pass it on to early adopters who find the relative advantages (even if it takes considerable effort)
3. Use these opinion leaders/champions to take it across the "chasm" to the early/late majorities



[Rogers, 1962]

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Diffusion of Innovations…

SE Tool success requires:

- Make your pioneers/champions successful
- Give them opportunities to talk/communicate successes
- Give them a career path to support the innovation (Design Centers,…)

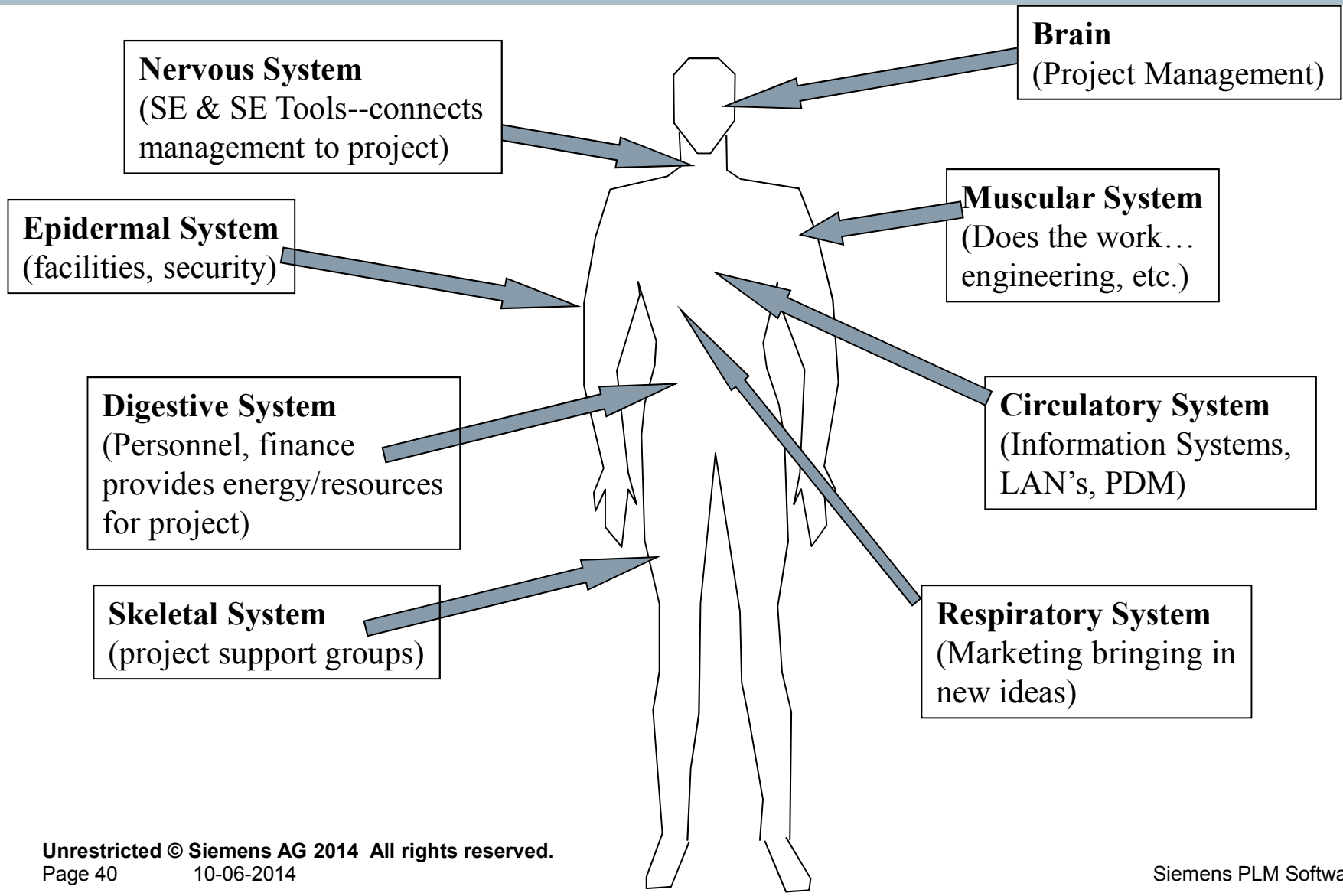
Ideas on communicating success:

- SE Newsletters, includes Tools
- Brown Bag Sessions on Tools
- Tool Roadshows
- Special Interest Groups
- User Groups
- SE Training Classes include tools
- Process training tied to tools

Pioneer Aptitude Test	Y	N
Pioneers keep up with trade journals, computer magazines, etc.		
Pioneers work on computers at home--i.e., they don't get enough at work		
Pioneers are always looking for new ways and tools to help them do their job (they may even go buy the tool themselves)		
Pioneers are known throughout their project as the first to adopt any new technology that comes along and come up with new and unique ways of applying the tools		
Pioneers are the informal support person in the project (project folks go to them for help on the tools)		
Pioneers are almost always positive on what tools can do for the project		
Pioneers are willing to put in a lot of work to make the tools work		

[Rogers, 1962]

Anatomy of an project…



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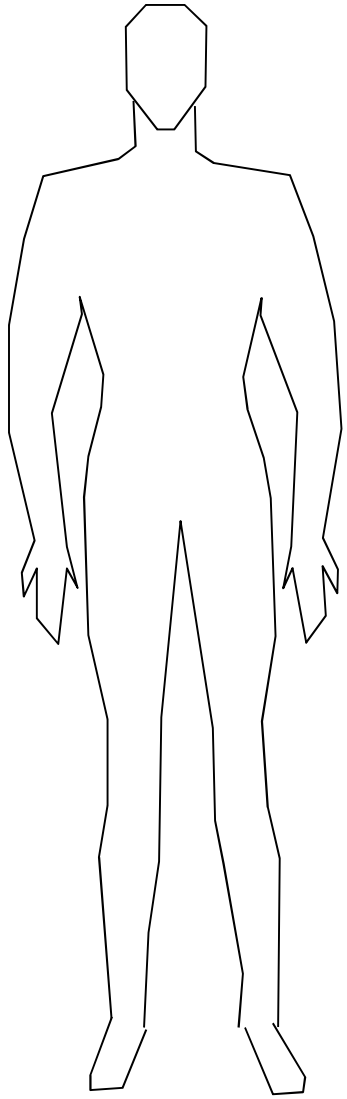
Transplant process…

- Transplant overview/process
- Medical ethics and priority
- Organ function and symptoms
- Social aspects with families,…
- Finances…cost, acquisition, maintenance,…
- Dietitian…weight, nutrition, physical condition,…
- Pharmacology…anti-rejection, side effects, infections,…
- Case worker…prequalification, tests, clearances from…
- Legal…living wills, etc.
- Surgeon…risks, etc.



Transplanting MBSE into an organization…

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- Transplant/tool overview/process—agreed new process
- Medical/tool ethics and priority—agreement on when tools will/will not be used, buy in from organization,…
- Organ/tool function and symptoms—understanding of what functions the tool will perform and what symptoms it addresses
- Social aspects with organization—support organization to support the tools, PR campaign, internal user group,…
- Finances…cost, acquisition, maintenance,--financial budget to cover implementation/maintenance of tools
- Tool Dietitian…weight, nutrition, physical condition—training plan, deployment plans, maintenance, etc.
- Pharmacology…anti-rejection, side effects, infections,--tool usage incentives, metrics, opportunities, etc.
- Case worker…prequalification, tests—on site support, who can use it, etc.
- Surgeon…risks—Project, IT, and Design Center Mgmt