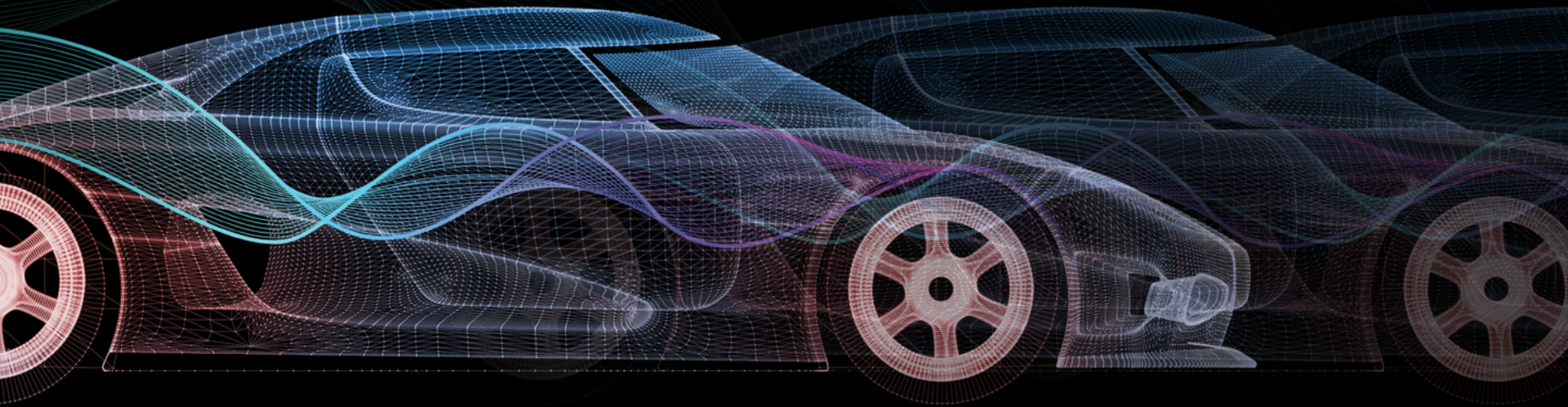# Set-Based Concurrent Engineering: Cultural Aspects and Benefits
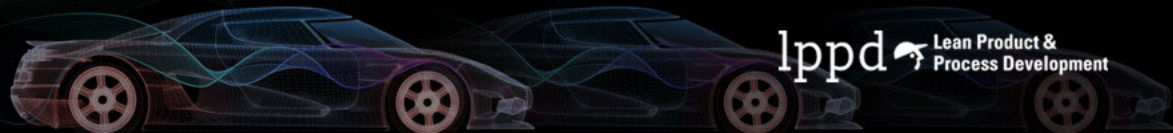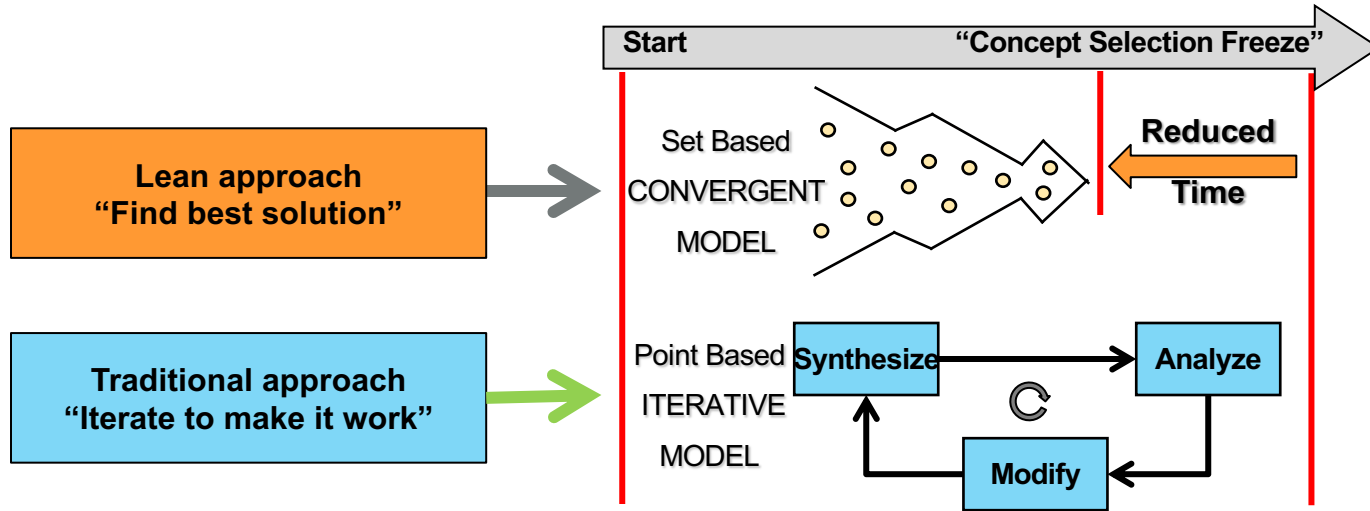
Presented By John Drogosz, Ph.D.

Designing the Future Summit 2018

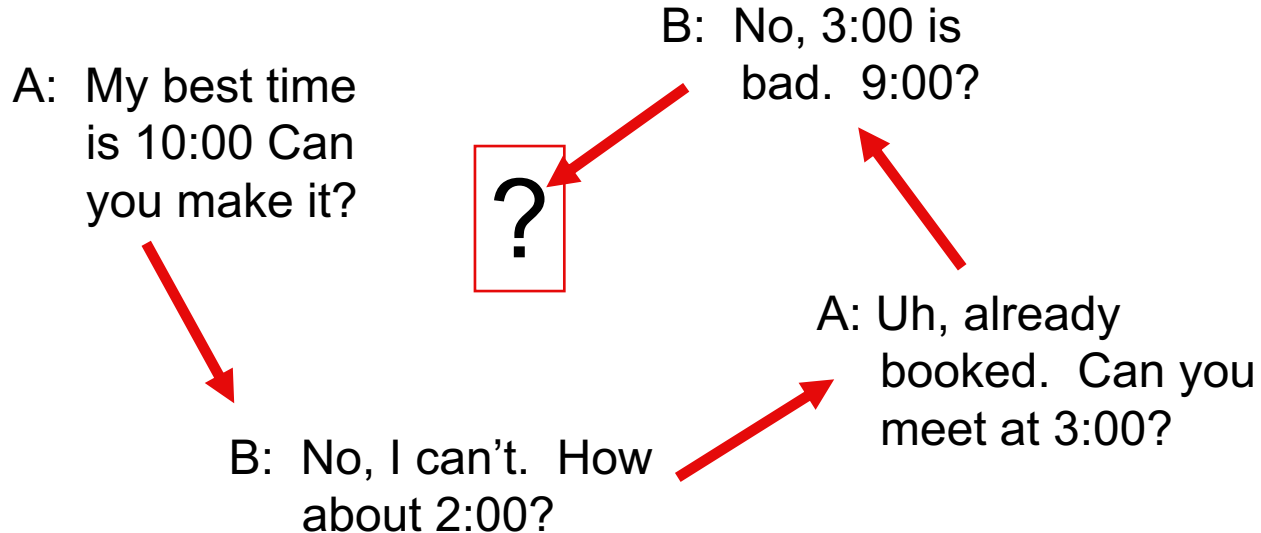lppd **Lean Product & Process Development**

Set-Based Development

Lean approach "Find best solution"

Traditional approach "Iterate to make it work"

Start   "Concept Selection Freeze"

Set Based CONVERGENT MODEL

Reduced Time

Point Based ITERATIVE MODEL

Synthesize → Analyze → Modify

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A Simple Example: Point-Based

Setting up a meeting using the point-based model

A: My best time is 10:00 Can you make it?

B: No, 3:00 is bad. 9:00?

?

B: No, I can't. How about 2:00?

A: Uh, already booked. Can you meet at 3:00?

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J. Morgan 200

A Set-Based Approach

Now setting up the meeting by communicating about <u>sets</u>

A: I can meet 10:00 - 1:00 or 3:00 - 5:00 Can you make any of these times?

→

B: Let's meet 12:00 - 1:00

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# Traditional Concept Exploration
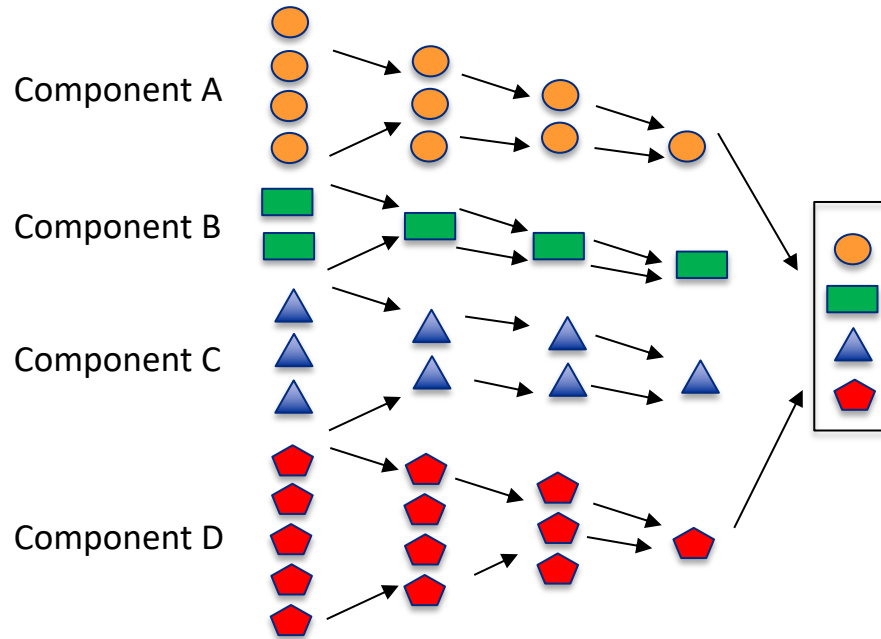
- The 'best' solution for each system is chosen

- The 'best' solution may not lead to the 'best' overall solution as compatibility between sub-systems are not understood

- A lot of iterations later to 'fix' the interface issues & trade-offs that typically arise

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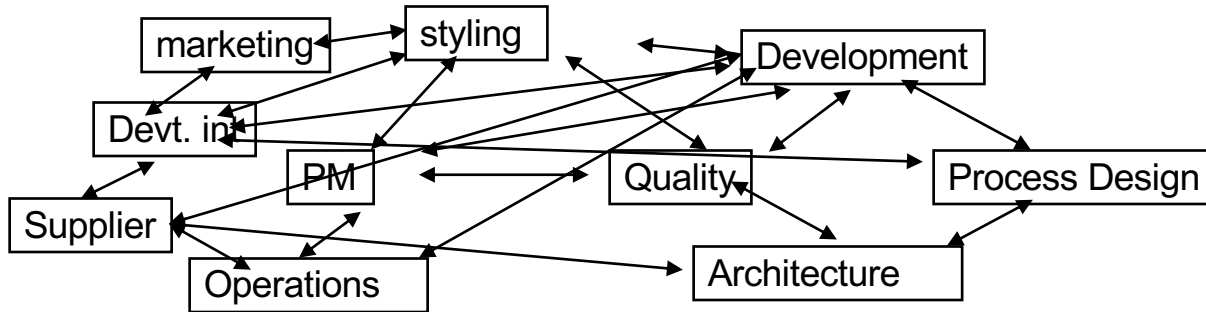# "Accelerated" Concept Exploration Approach
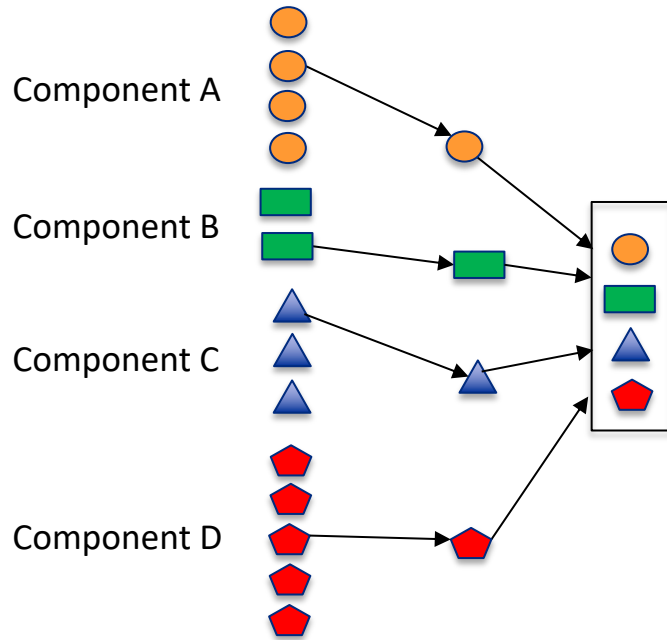
- Pressure to move quickly into developing the solution

- Don't fully explore the design space

- Rush to a "winner" with minimal knowledge

- Rework the design in the development phase

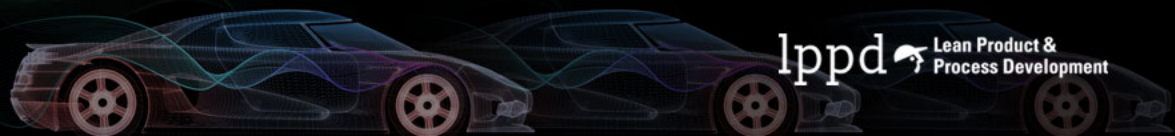lppd Lean Product &
Process Development
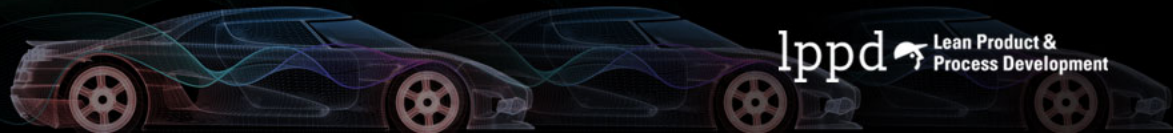
Challenges with the Point-Based Approach

- Causes us to pass a solution around, each member making changes
- Each change causes further changes and we never get a clear picture of the possibilities.
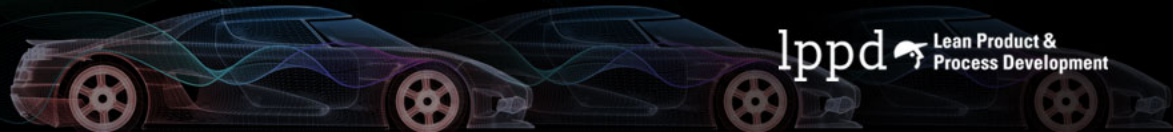
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Set-Based Philosophy

Generating multiple potential solutions to a design or engineering challenge and working through a convergence process to achieve the best possible solution.
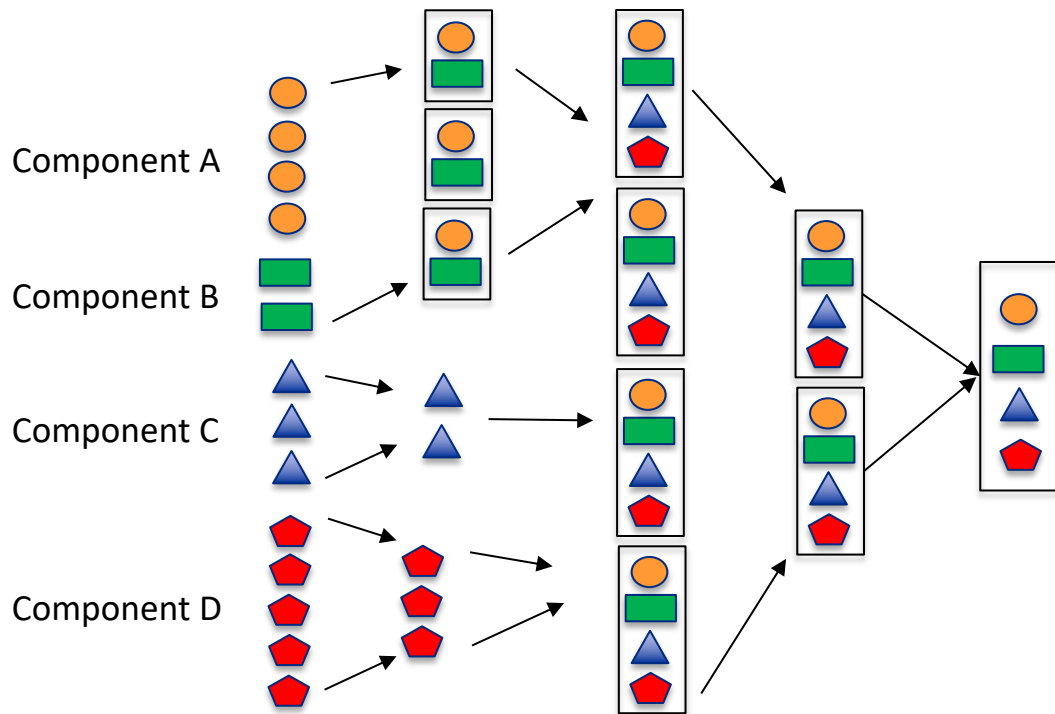
- Dr. Al Ward

Pursue innovative ideas while managing uncertainty in design

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# Set-Based Concurrent Engineering (SBCE)

- Develop enough knowledge to understand which alternatives to eliminate

- Keep building knowledge around the remaining alternatives over time and keep eliminating weaker alternatives

- Use integration events to ensure compatibility

- Final selection is ultimately made with significant amount of accumulated knowledge

- High confidence in selected solution to go into detailed design

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"I don't play my 11 best players.
I play my best 11 players"

Bear Bryant
Former Alabama Football Coach

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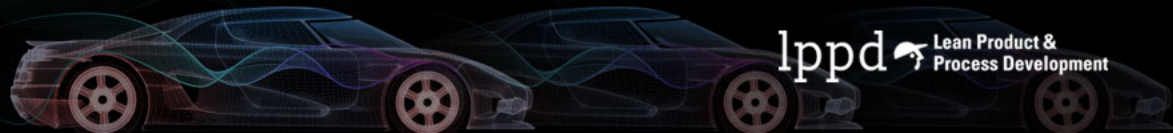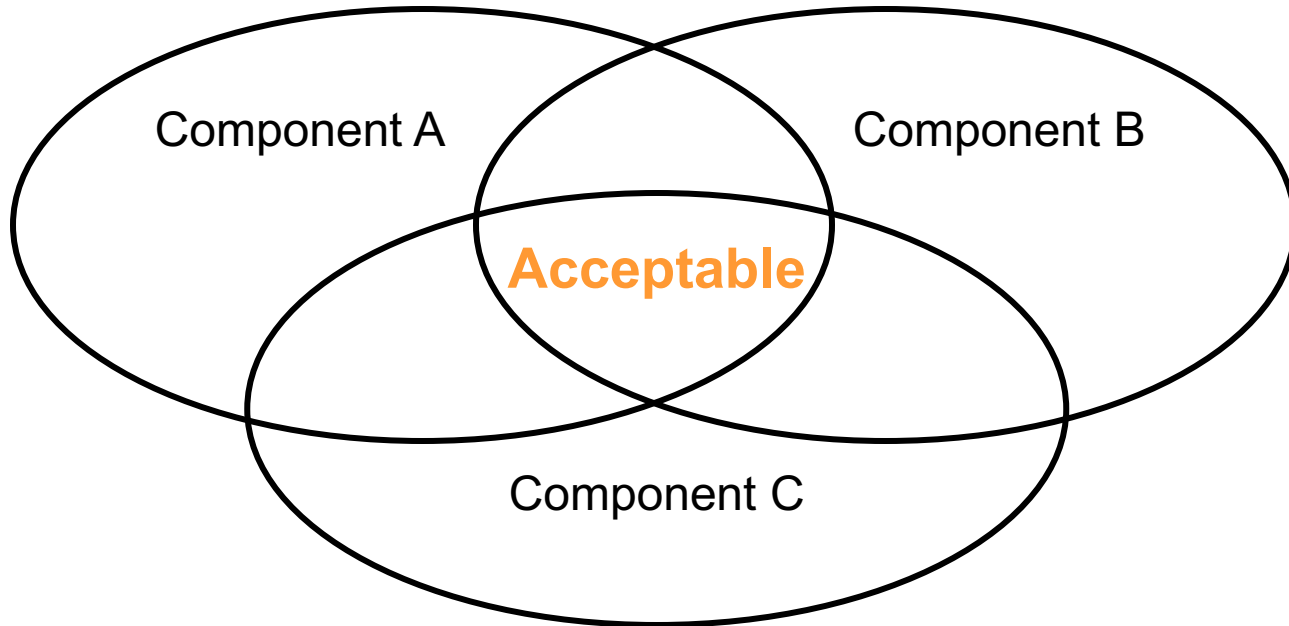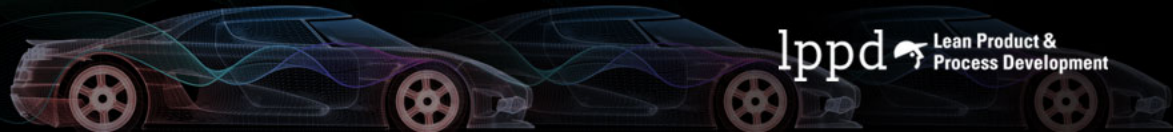
Set-Based Perspective

System Integrator & teams look for intersections between feasible sets of alternatives to arrive at best system-level solution

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SBCE EXERCISE

Cultural Aspects and Benefits

lppd **Lean Product & Process Development**

Set-Based Simulation Exercise
Card Game: Round #1

Teams of 5 players

Objective: Try to have the "optimal hand" with 5 cards

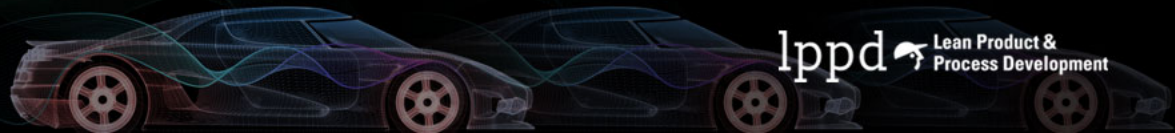lppd **Lean Product & Process Development**
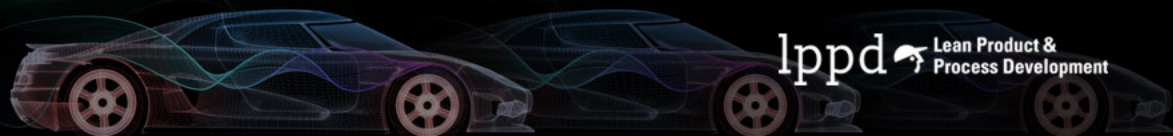
Set-Based Simulation Exercise
Card Game: Round #1

Scoring:

- Face cards = 10 points
- Other cards = face value (e.g. ace=1,2,3,4..9)

Bonus:

- All the same color (black or red) = +10 points
- All the same suit (spade, heart,etc) = +25 points
- 4 of one kind (e.g. aces, jacks, etc) = +50 points
- 5 all in sequence in same suit (4,5,6..) = +50 points

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Set-Based Simulation Exercise
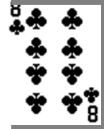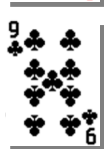# Card Game: Round #1

Game play:

- 5 total plays
- Each player initially selects 1 card from the deck
- Up to 4 additional plays where, team assesses score and may:
  - Stop and keep the existing hand as-is
  - Keep some cards, reject others and re-draw from deck

Costs:

- -1 for each initial draw (play 1)
- - 3 for each additional draw (plays 2,3)
- - 5 for each additional draw (plays 4,5)

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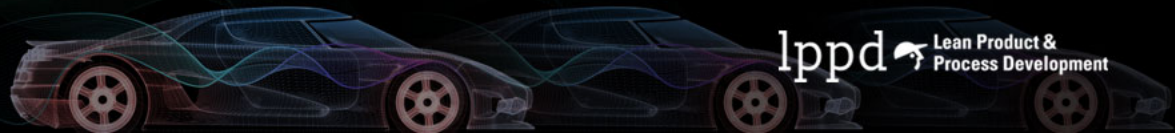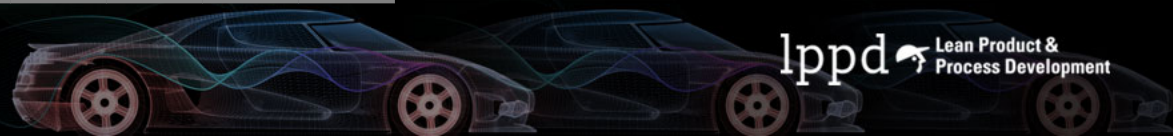
Example of play...

Cost

Play 1   -5

Play 2   -9

Play 3   -3

Play 4   -5

Play 5   -5

Final Hand: Score + Bonus - Cost
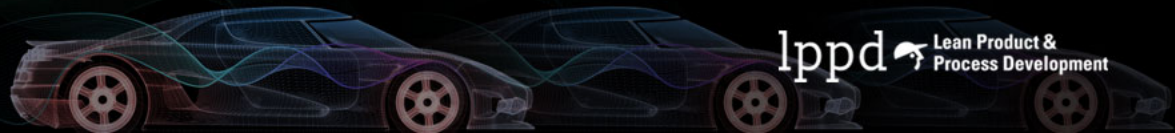
= 46 +   50   – 27 = **69 points**

Round #1: Now let's play…

Assign a scorekeeper in your team to capture score throughout the exercise

Play the game twice to compare results

Provide final scores and number of iterations to the facilitator

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Set-Based Simulation Exercise
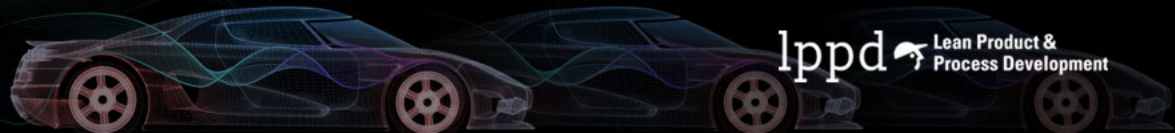# Card Game: Round #2

Scoring:

- Face cards = 10 points
- Other cards = face value (e.g. ace=1,2,3,4..9)

Bonus:

- All the same color (black or red) = +10 points
- All the same suit (spade, heart,etc) = +25 points
- 4 of one kind (e.g. aces, jacks, etc) = + 50 points
- 5 all in sequence in same suit (4,5,6..) = +50 points

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Set-Based Simulation Exercise
Card Game: Round #2

Game play:

- Each player initially draws 5 cards from the deck
- Team members compare "sets" of cards to create the highest possible scoring hand

- Costs:
  - -3 for each player for 5 draws
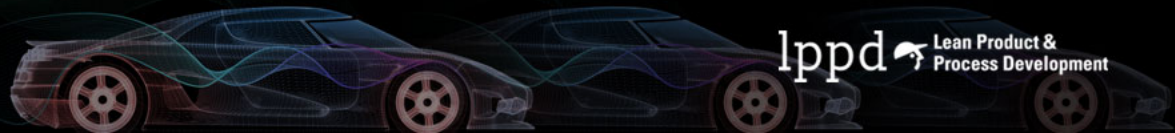 - Total Team cost = - 15 points

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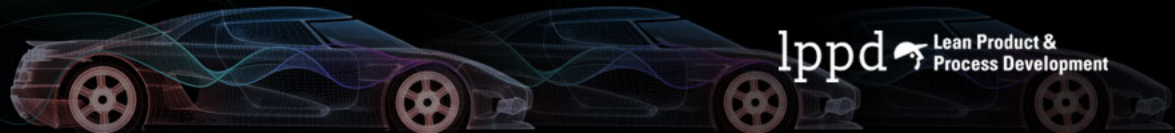
Round #2: Let's play again…

Assign a scorekeeper in your team to capture score throughout the exercise

Play the game twice to compare results

Provide final scores to the facilitator

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Debrief: Group Discussion
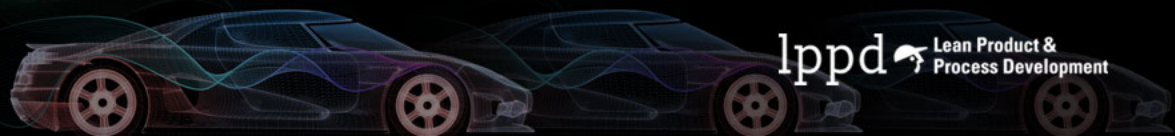
lppd **Lean Product & Process Development**
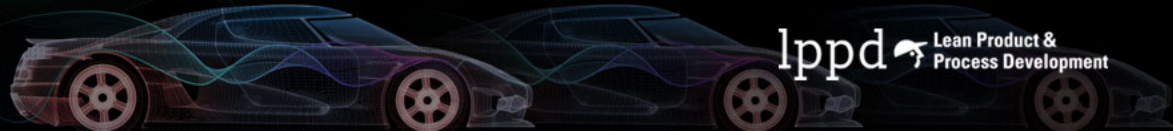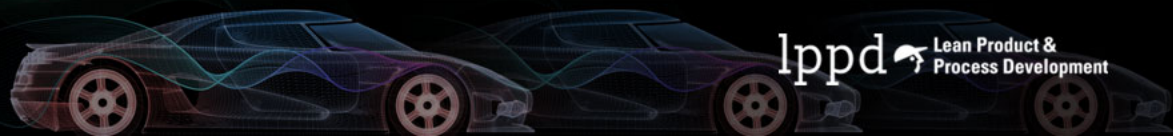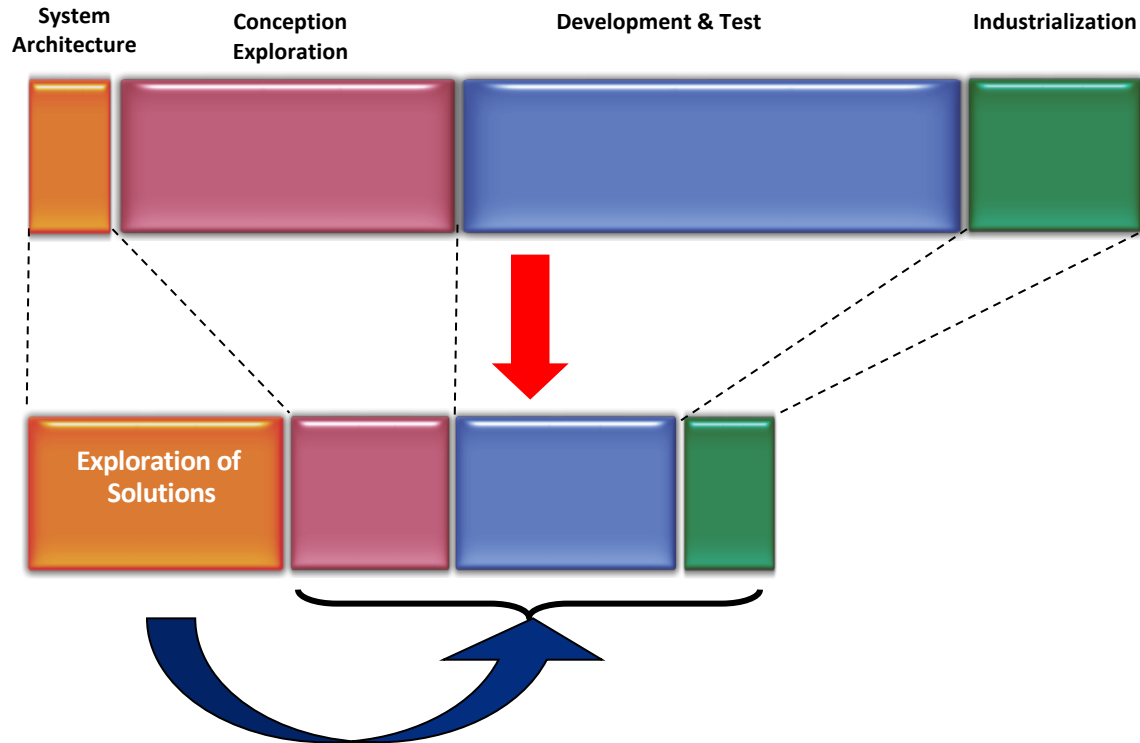
Discussion points

Compare scores – within teams and between teams. What do you see?

What are the benefits you saw between the first and second rounds?

What cultural behaviors did you observe in the first versus the second rounds?

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Front-load to throroughly explore alternatives

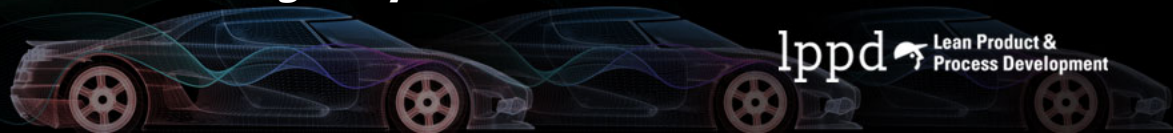lppd Lean Product & Process Development

SBCE Approach: Getting Started

PREPARATION
Scope, objectives, participants, data

WORKSHOP
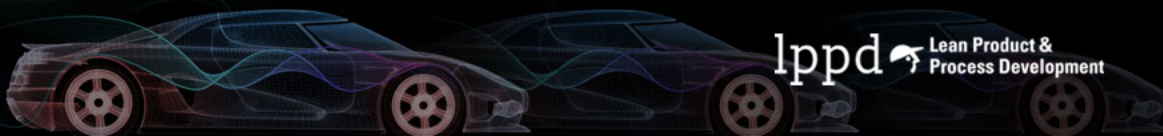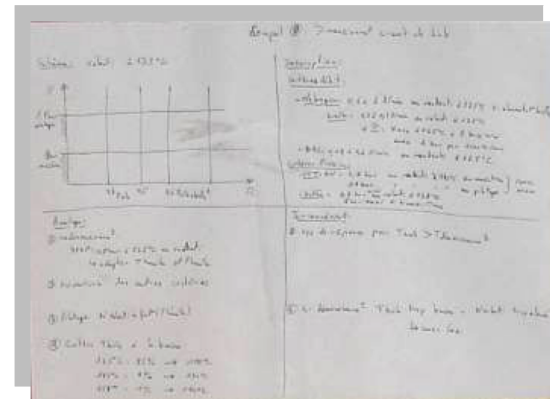(initialization of SBCE)
2 – 3 days dedicated teamwork

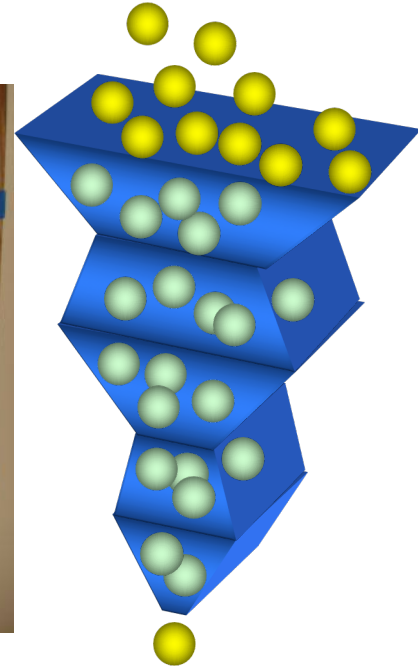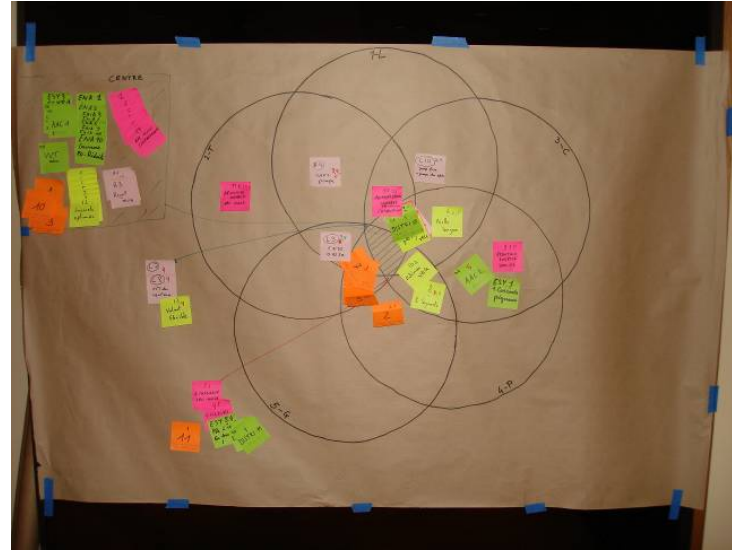**FOLLOW UP**
Action Plans
Integration Events
Knowledge Capture

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Working in Sub-Groups

Document each concept on 1 page

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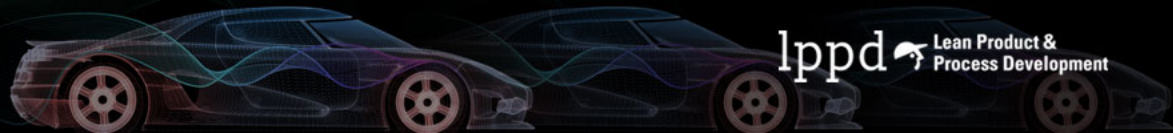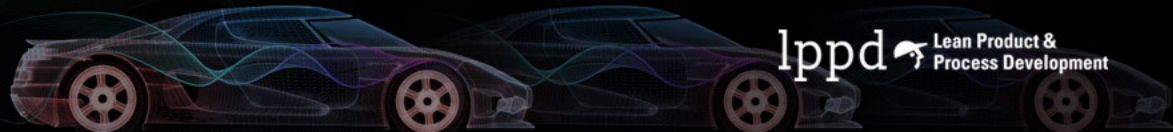
Evaluation and Compatibility

- Present Concepts
- Evaluate Compatibility
- Eliminate weaker alternatives

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Process Development
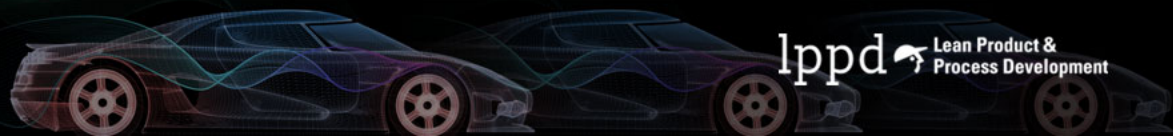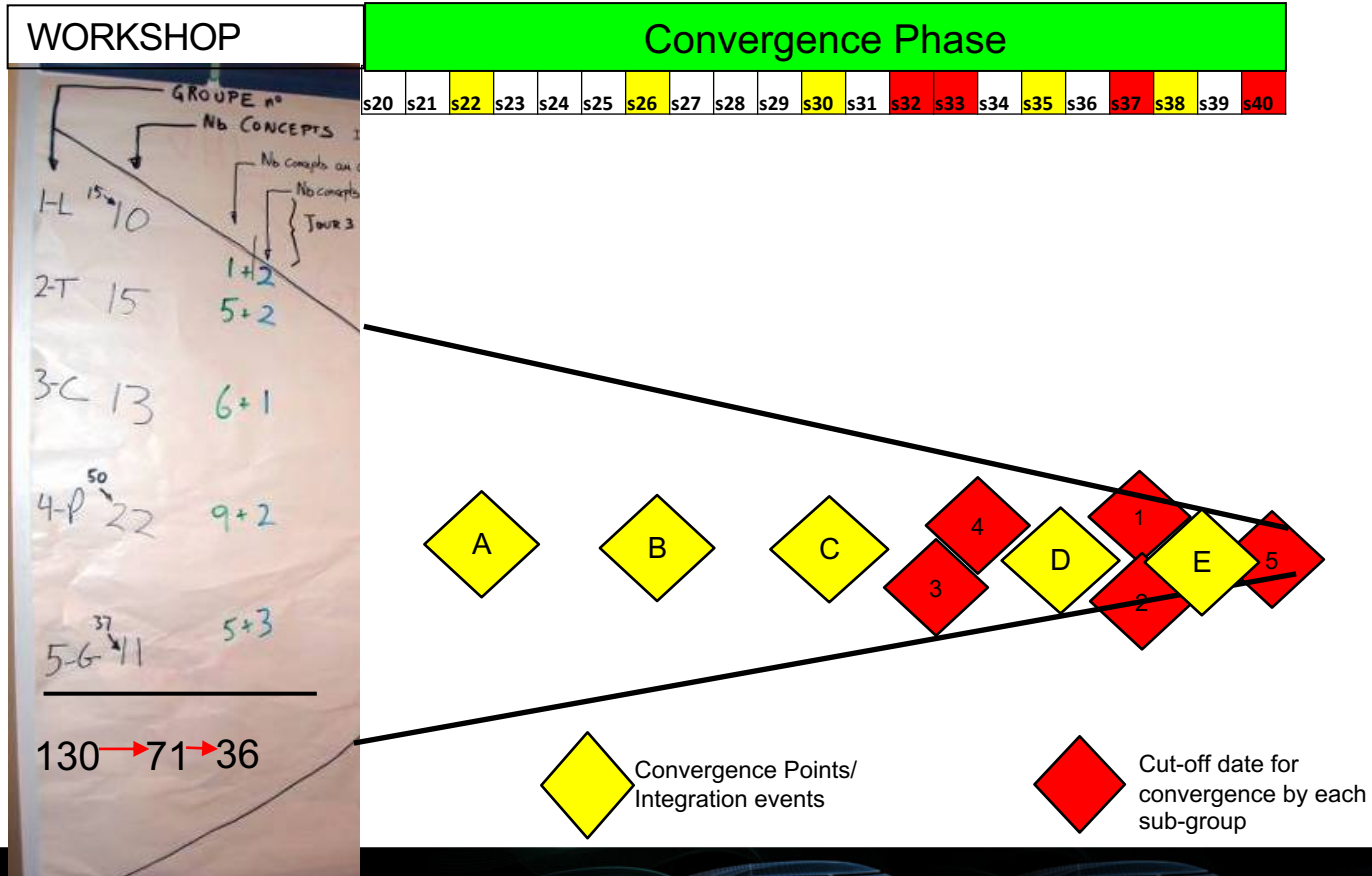
Convergence Phase & Set Expansion

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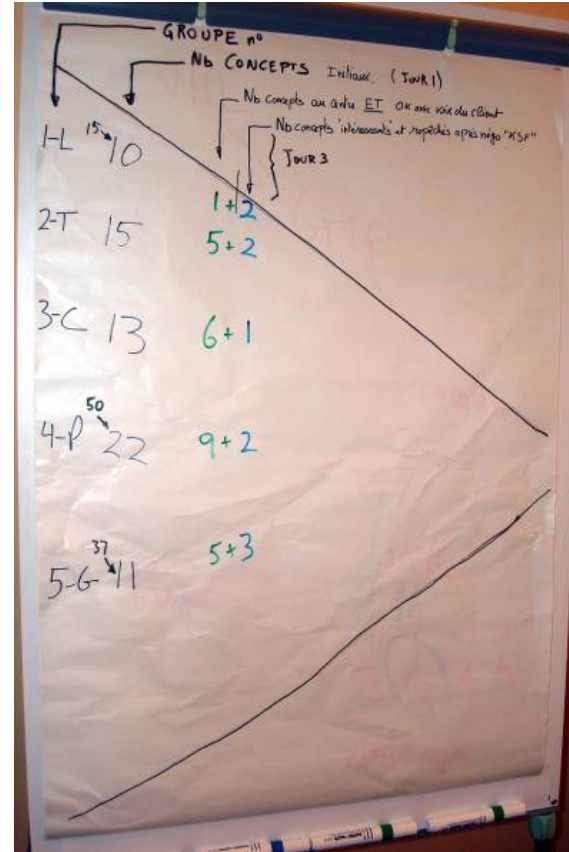
Kentou (Study) Phase convergence

WORKSHOP	Convergence Phase																			
	s20	s21	s22	s23	s24	s25	s26	s27	s28	s29	s30	s31	s32	s33	s34	s35	s36	s37	s38	s39	s40

A   B   C   4   D   1   E   5
                3   2

◆ Convergence Points/
  Integration events

◆ Cut-off date for
  convergence by each
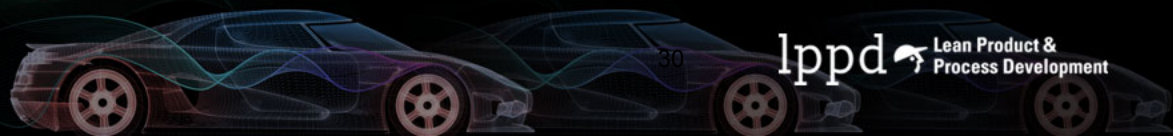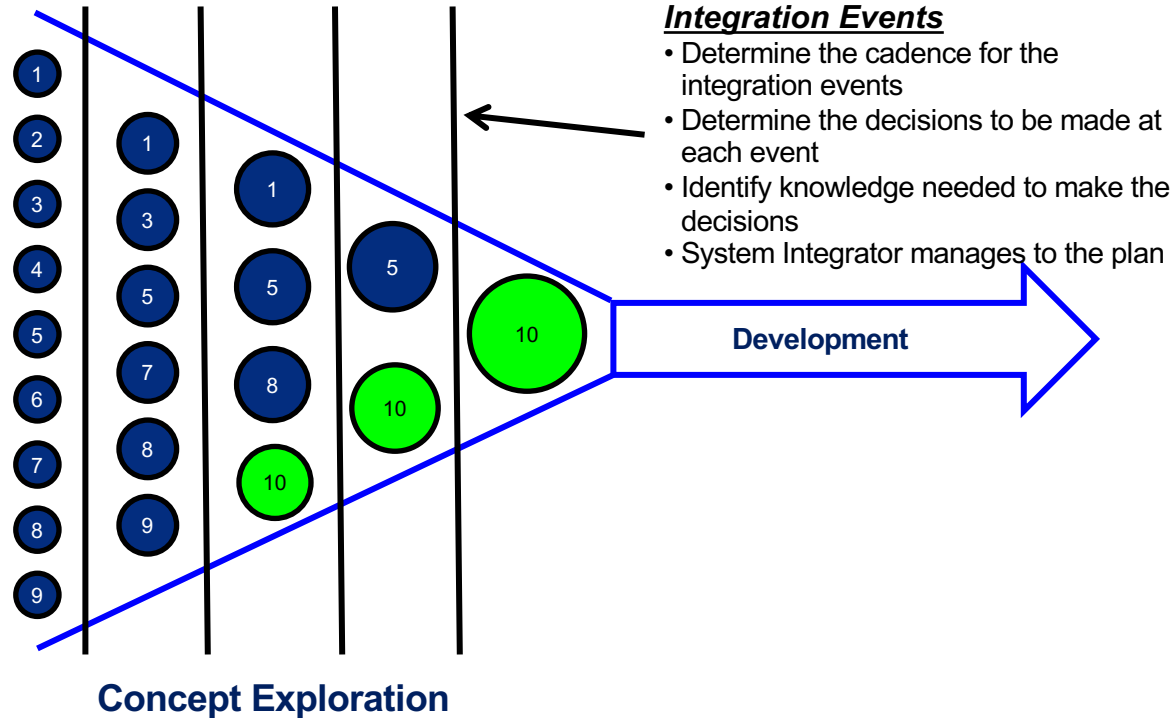 sub-group

130 → 71 → 36

Hedging: Innovation vs "Failure"

Simultaneous pursuit of multiple alternatives provides robustness against engineering failure.

- Problem is broken down as far as possible, and multiple approaches pursued to each sub-problem
- Pursue both radically innovative and conservative approaches (Backup) in parallel
- Decision dates set to show success based on knowledge generated for innovative/radical alternatives

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Adapted from J Morgan 2006

Set-Based Concurrent Engineering

Integration Events
- Determine the cadence for the integration events
- Determine the decisions to be made at each event
- Identify knowledge needed to make the decisions
- System Integrator manages to the plan

**Development**

Concept Exploration

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Kentou (Study) Phase: Follow up

Key Points:

• Document all solutions that have been explored during the Kentou phase in a designated repository as they may be applicable to future projects.

Key success factors:

- All disciplines respect decisions made by the team.
- Avoid going back to second-guess or re-explore solutions already eliminated.
- Decisions are made when specified on the convergence plan based on the knowledge generated

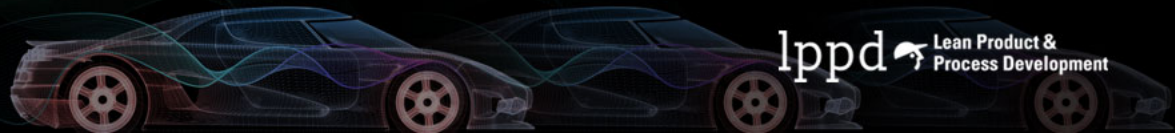lppd **Lean Product & Process Development**
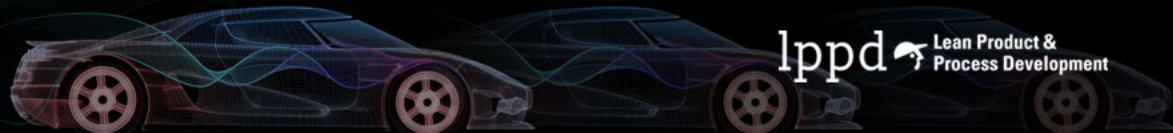
Capturing and Re-using knowledge
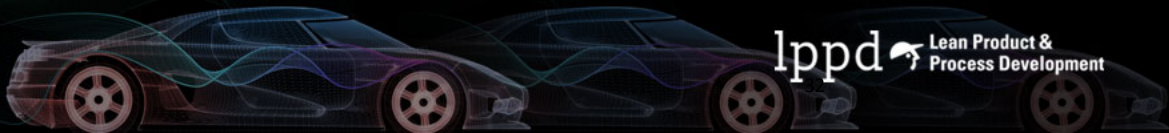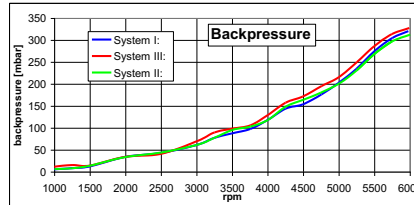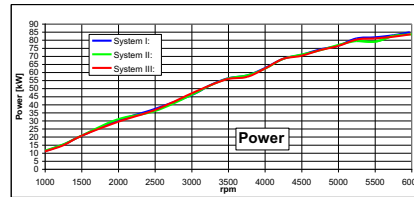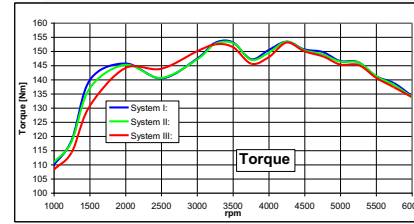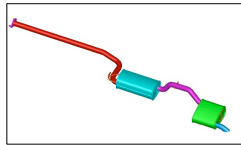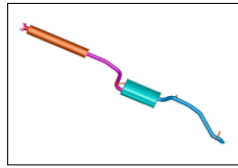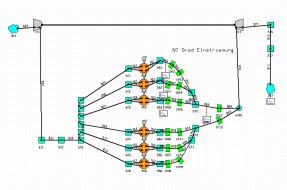
Conclusions: Front-loading & SBCE

- Encourages innovation & risk-taking upfront

- Encourages growth and sharing of knowledge

- Encourages multi-discipiline collaboration

- Helps better manage technical & project risks

- Reduces the probability of late (and costly) "discoveries"

- Drives a structured cadence of decision-making

- Optimizes system solutions that best meet our customers' needs

SBCE helps to drive the cultural aspects of Lean PPD into an organization (e.g. customer first, rapid learning and continuous improvement)

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Q and A

Thank You

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