

# Using Chord Diagrams in JMP to Assess Multiple Approaches to Shorten the Development Lifecycle



## PRESENTED BY

Ed Carroll, Principal Systems Research Analyst  
Thor Osborn, Principal Systems Research Analyst  
Sandia National Laboratories



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## ABSTRACT

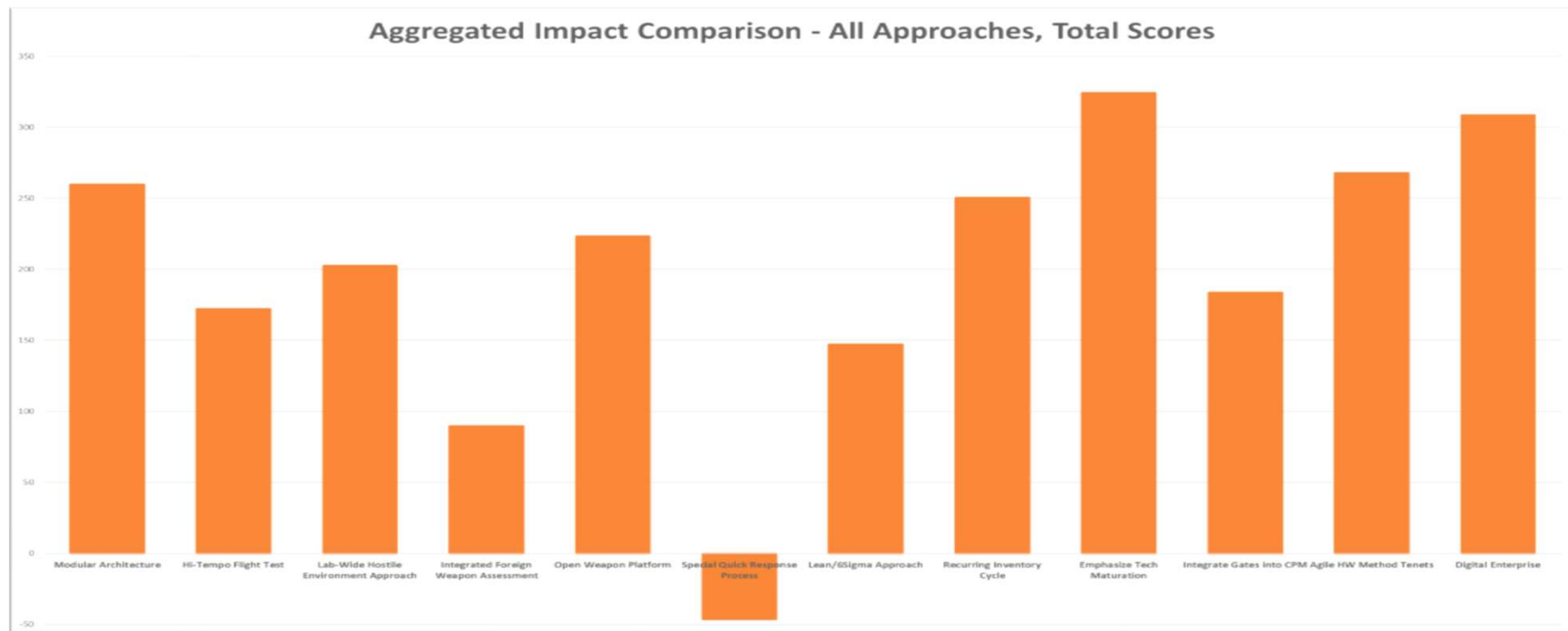
- Sandia National Laboratories is working on approaches and innovations that have the potential to transform Sandia's engineering enterprise.
- An impact assessment was conducted, where subject matter experts were asked to evaluate the impact of twelve different approaches on the existing development processes.
- A chord diagram was used to illustrate the results of the impact assessment based on the relationships between the approaches.
  - The chord diagram is not native to JMP, so a routine in 'R' was developed and executed from within JSL.
- The chord diagrams illustrated that approaches with the highest impact were felt when approaches were combined.
  - In other words, the beneficial effects were cumulative.

- **Modular Architecture**
  - An agile and responsive architecture
- **Hi-Tempo Flight Tests**
  - Enabling rapid test exploration cycles
- **Open System Platform**
  - Lowering threshold of engagement
- **Lab-wide Environment Collaboration**
  - Improved requirements definition
- **Integrated Foreign System Assessment**
  - Improved requirements definition
- **Special Quick Response Processes**
  - We responded quickly in the past
- **Recurring Inventory Cycles**
  - Touch every system every 10+ years
- **Lean / 6-Sigma Approach (enterprise-wide)**
  - Continuous process improvement-by everyone
- **Emphasize Readiness and Maturation**
  - Separate tech mat from program schedules/funding
- **Integrate Phase Gates into Program Critical Path**
  - Allow milestone dates to change as schedule changes
- **Agile Hardware Methodology Tenets**
  - Reprioritize work at each sprint, Test 1<sup>st</sup>, highly engaged customer
- **Digital Enterprise**
  - Fundamental for integrated designs, and reduced defect

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## BACKGROUND



In the real world, several approaches are being implemented simultaneously. This chart of total raw scores indicates that the most positive impact is from Emphasizing Tech Maturation, Digital Engineering, and Modular Architecture. Are they the right approaches? We wanted to know what the combined impact would be.

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## JSL/R SCRIPT

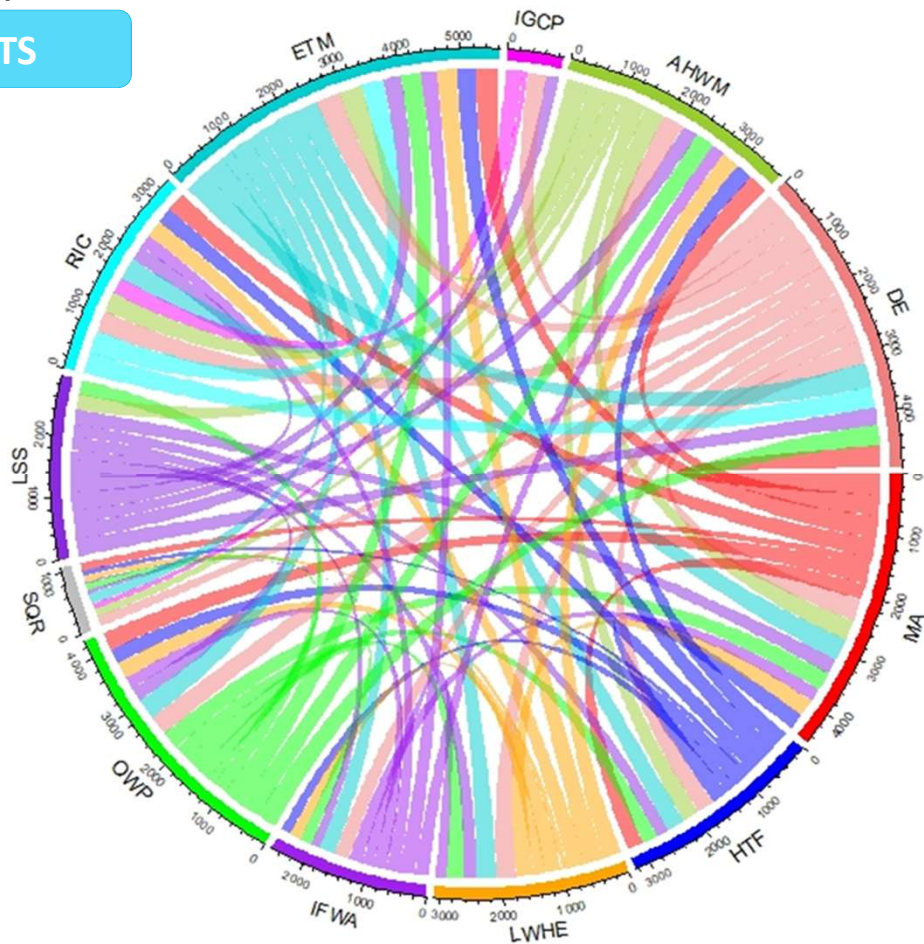
We used the chord diagram to illustrate the results of the impact assessment and to illustrate the relationships between the approaches

The chord diagram is not native to JMP, so a routine in 'R' was developed and executed from within JSL.

```
Names Default To Here( 1 );
Clear Log();
//
//Send data and commands to R, creating a chord diagram, and pulling the results back to JMP
//
R Init();
//
/*Assign row and column colors*/
//
gcolors = {"brown", "blue4", "darkorange", "darkorchid", "chocolate3", "chartreuse", "darkslateblue",
"darkslategrey1", "lightseagreen", "mediumvioletred", "yellow1", "tan2"};
ccolors = {"red", "blue", "orange", "purple", "grey", "green", "blueviolet", "Cyan", "darkturquoise",
"magenta", "yellowgreen", "lightcoral"};
//
//Set data table as an 'R' matrix
//
pmat = current data table () << Get As Matrix ({2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13});
:"Approaches" << Set Selected(1);
rnames = {"MA", "HTF", "LWHE", "IFWA", "OWP", "SQR", "LSS", "RIC", "ETM", "IGCP", "AHWM", "DE"};
cnames = {"MA", "HTF", "LWHE", "IFWA", "OWP", "SQR", "LSS", "RIC", "ETM", "IGCP", "AHWM", "DE"};
//
//Set data table as an 'R' matrix
//
//Set data table as an 'R' matrix
//
R Send(pmat);
R Send(rnames);
R Send(cnames);
R Send(gcolors);
R Send(ccolors);
R Submit("\[
  library(circlize)
  rownames(pmat) = rnames
  colnames(pmat) = cnames
  grid.col = NULL
  grid.col = c( MA = "red", HTF = "blue", LWHE = "orange", IFWA = "purple",
  OWP = "green", SQR = "grey", LSS = "blueviolet", RIC = "cyan", ETM =
  "darkturquoise", IGCP = "magenta", AHWM = "yellowgreen", DE = "lightcoral"
  )
  chordDiagram(pmat, grid.col = grid.col)
  circos.clear()
]\");
picture = R Get Graphics("png");
New Window("Picture", picture);
Wait(1000);
R Term();
```

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## RESULTS



• The Enabler color is in the outside bar; the Enabled approaches are the multi-colored paths

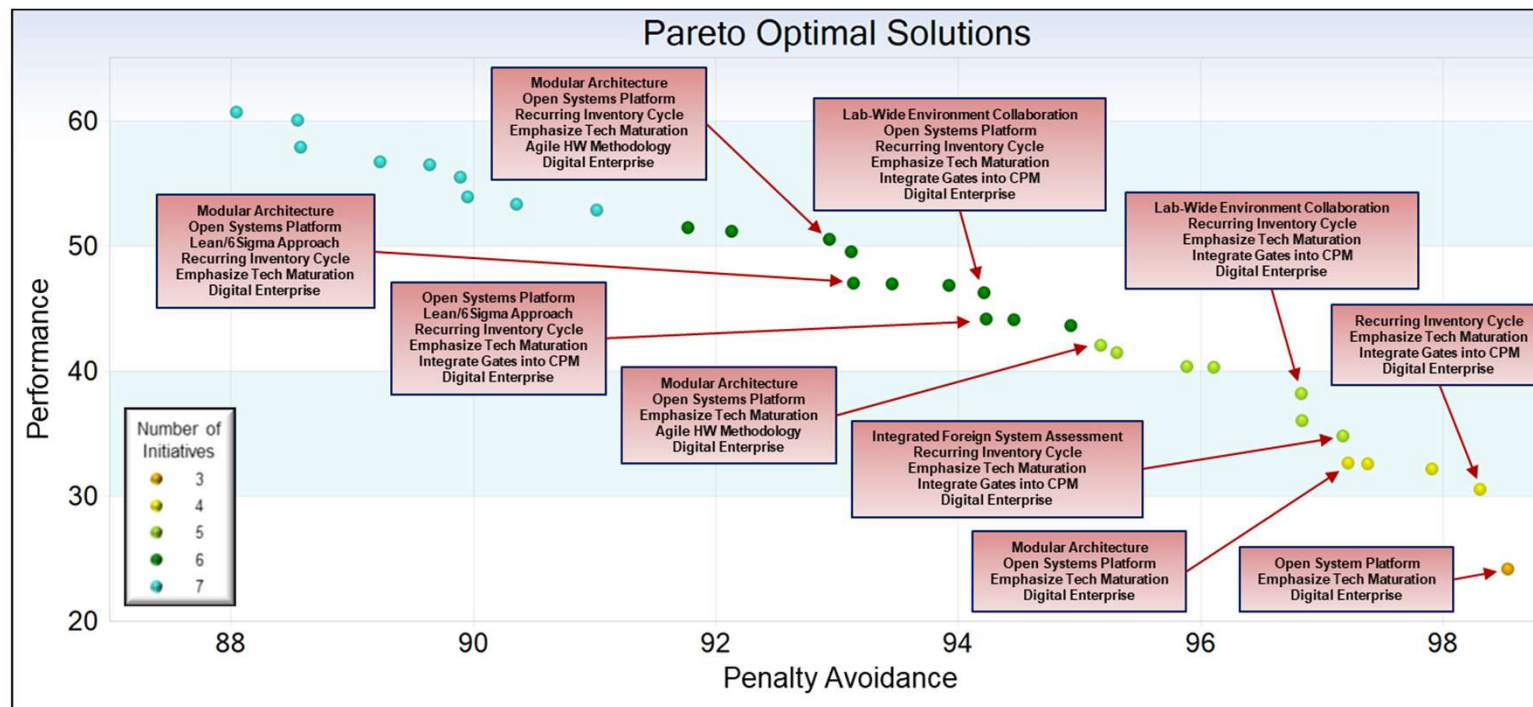
- This diagram shows the influence relationships between approaches. Notice that the 3 approaches with highest impact are key enablers for other approaches:
  - DE enables many approaches
  - ETM enables many approaches and is enabled by many
  - MA/OWP/AHWM enable/are enabled by many
  - LSS enables many
  - SQR is enabled by many
- This led us to question what was the optimal combination



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## FINDINGS



The Pareto Frontier chart illustrates that while EMT, DE, and MA are important, there is a cost penalty to adding Modular Architecture, while other (lesser) approaches provide performance advantages with little penalty.

This plot shows only those solutions on the Pareto Frontier that contain 7 to 3 approaches. Full process coverage was achieved with 3 initiatives. Penalty Avoidance became significant above 7 approaches. In total, there were 4,096 approach combinations evaluated (optimal solutions lie on the frontier edge, so other results are ignored).

NOTE<sup>1</sup>: Penalty Avoidance = various forms of cost, so positive results are to the right of the chart and negative to the left

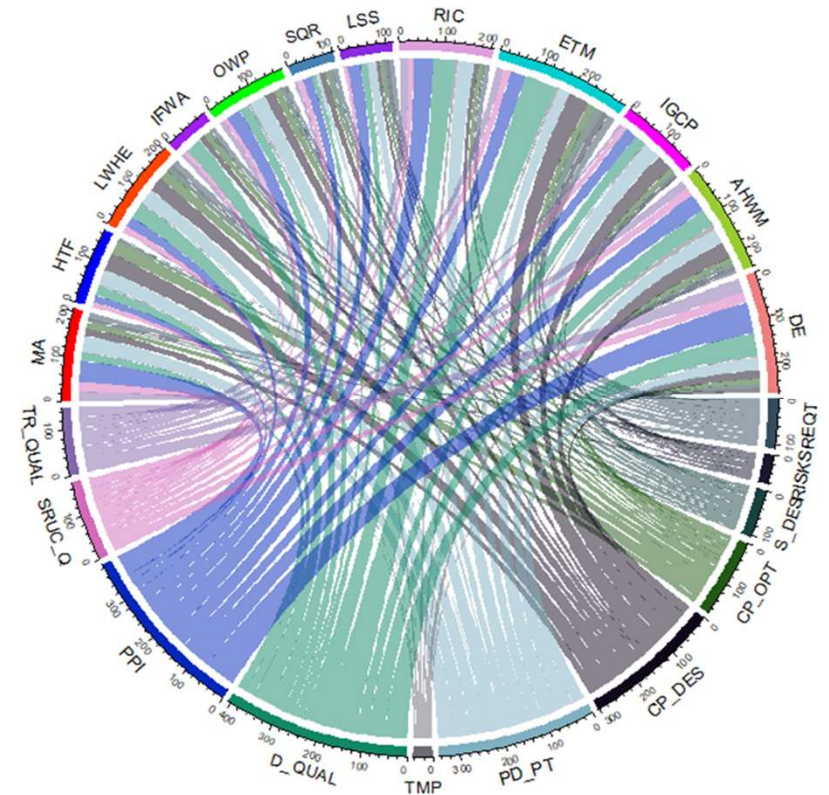
NOTE<sup>2</sup>: This plot was not created in JMP

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## CONCLUSIONS

- Chord diagrams provide an interesting visual representation useful in an impact assessment.
- JMP can be augmented to produce a chord diagram with relative ease
  - Perhaps we will submit a derivative of the 'R' routine as a JMP plugin
    - If you think we should create/submit a Chord Diagram JMP plugin, please feel free to contact the authors at: [ercarro@sandia.gov](mailto:ercarro@sandia.gov); [tdosbor@sandia.gov](mailto:tdosbor@sandia.gov)



This diagram shows the influence relationships between approaches and the development processes.

Notice:

- PPI, D\_Qual, PD\_PT are heaviest influenced
- MA/RIC/ETM/AHWM/DE are heaviest influencers

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## REFERENCES

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  - This free open-source software implements academic research by the authors and co-workers. If you use it, please support the project by citing the appropriate journal articles.
- Edwards, S, et al., “Whole Systems Trade Analysis,” *Proceedings of the 6<sup>th</sup> NDIA Ground Vehicle Systems Engineering and Technology Symposium (GVSETS)*, 2014.
- Henry, S., Waddell, L., and DiNunzio, M., “The Whole System Trades Analysis Tool for Autonomous Ground Systems,” *Proceedings of the 8<sup>th</sup> NDIA Ground Vehicle Systems Engineering and Technology Symposium (GVSETS)*, 2016.

