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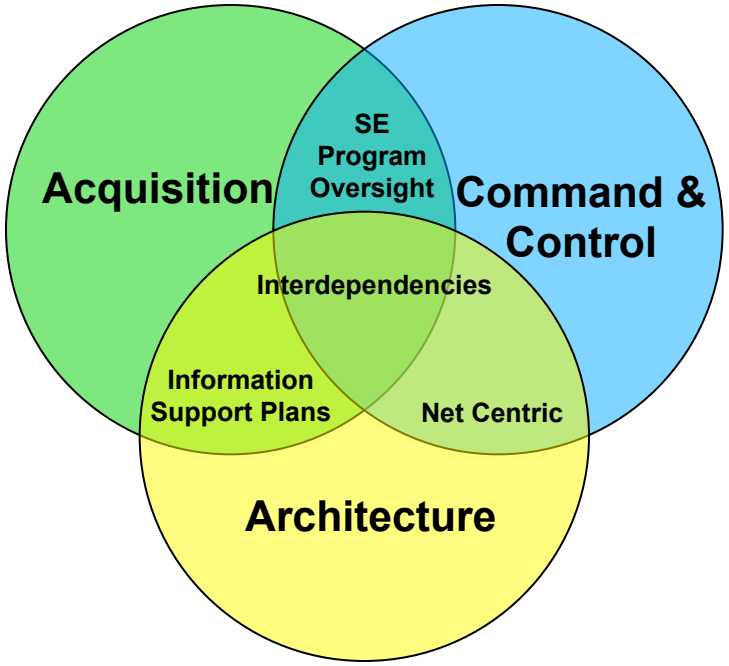
A Framework for Considering Cost Uncertainty within the Context of Complex Interdependent Systems

Education:
M.S. Systems Engineering (2007)
- Certification in Architectural-Based Integration

B.S. Computer Information Systems (2001)
- Minor in Management

Work Experience:
- Department of Defense Acquisitions
- Systems Interface and Integration
- C2ISR programs



June 21, 2011

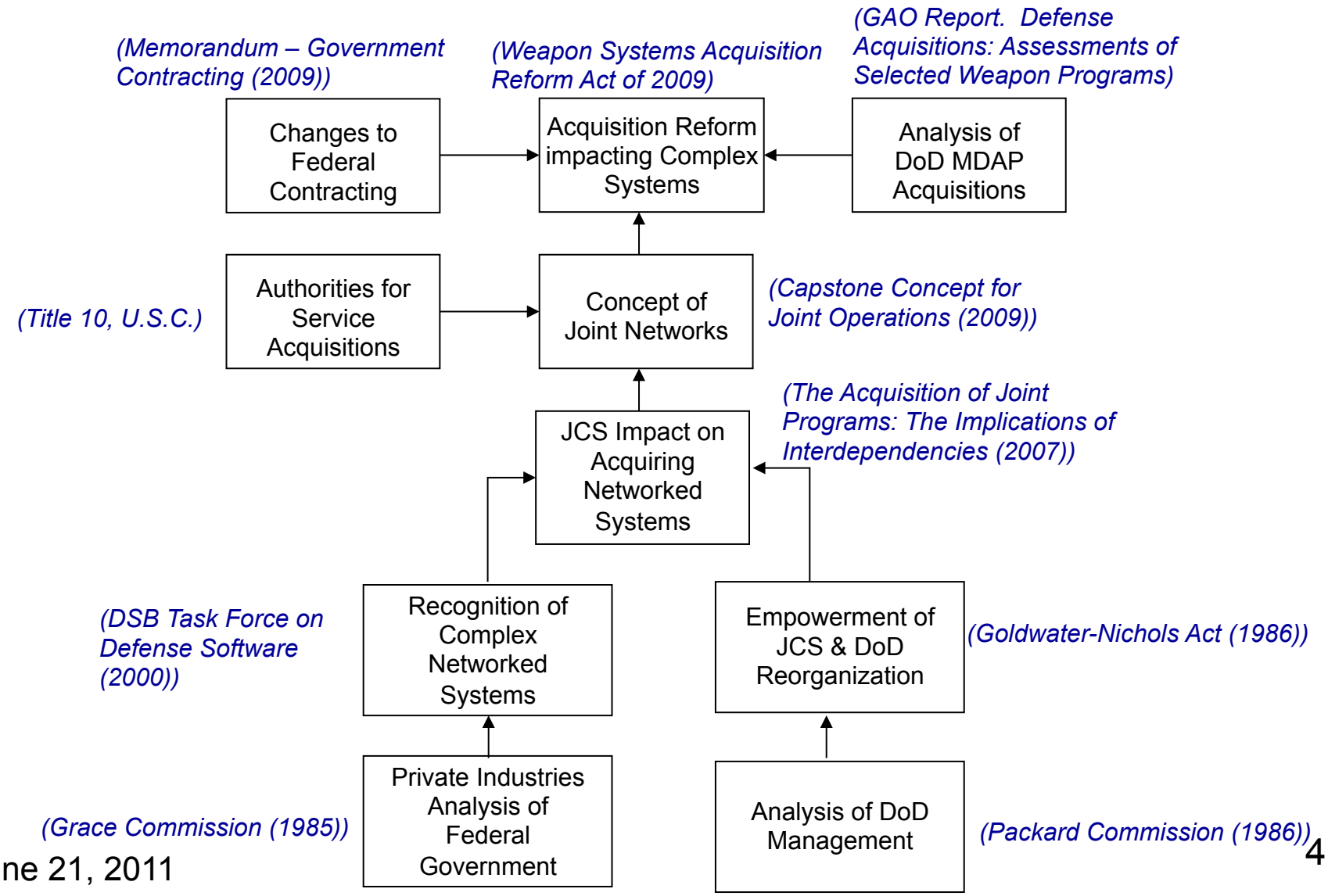
Agenda

- Problem
  - History
  - Example
  - Analysis - Non-Weighted Nodes
  - Analysis - Metcalf's Law
- Approach
  - Formula
  - Data Collection
  - Calculating Weighted Nodes
  - Calculating Cost
  - Analysis – Weighted Nodes
- Summary

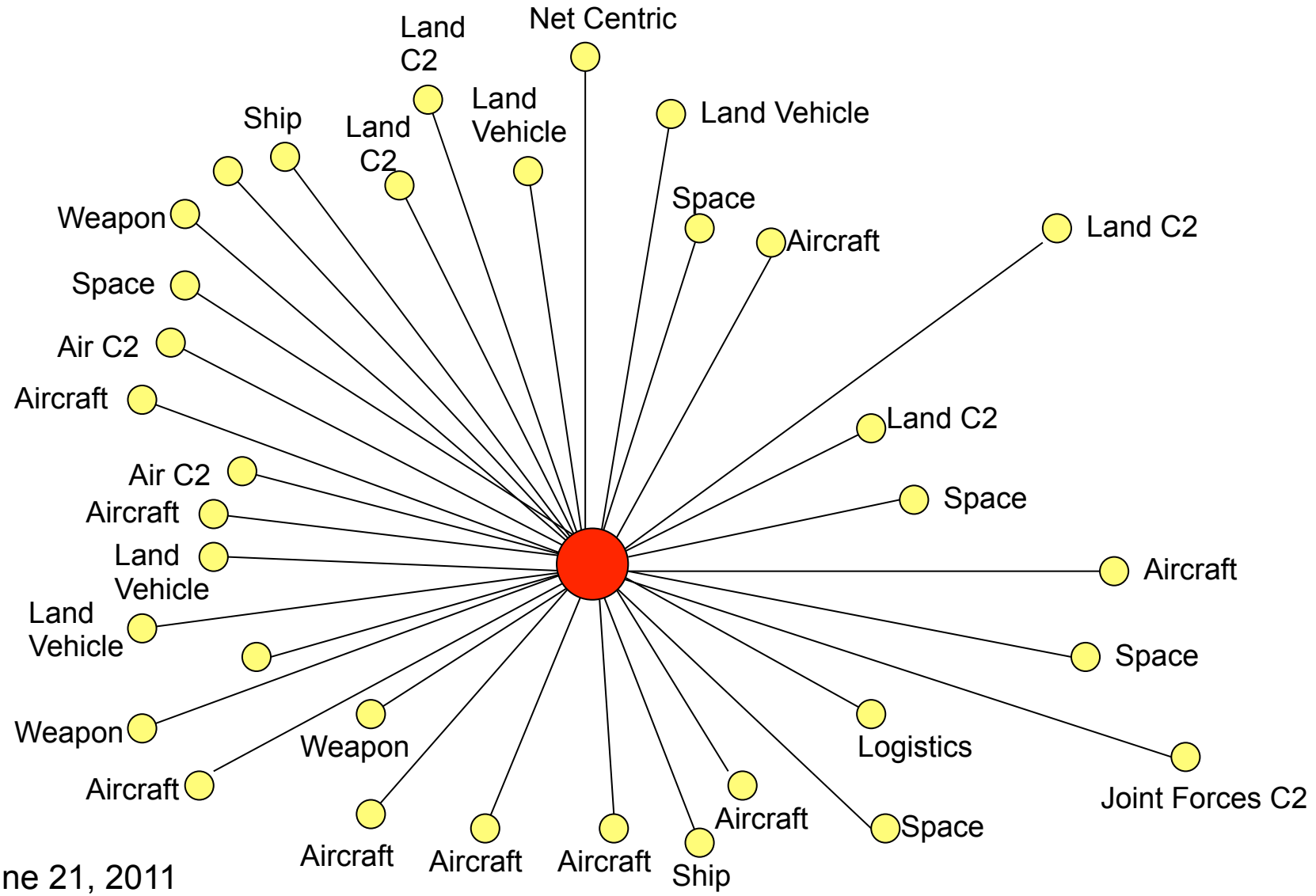
Problem

- Problem
  - Today's system developments have become very-complex and encounter unrelenting challenges that threaten their ability to deliver systems on time, within budget, and at the appropriate performance level
    - Insufficient tools and data available to quantify risks to a complex interdependent system
- Research Question
  - How does program interdependencies impact development cost?
- Contribution
  - To define a methodology for objectively assessing program interdependencies and characterizing related uncertainty in a way that informs resource allocation decisions and enables proactive risk mitigation efforts

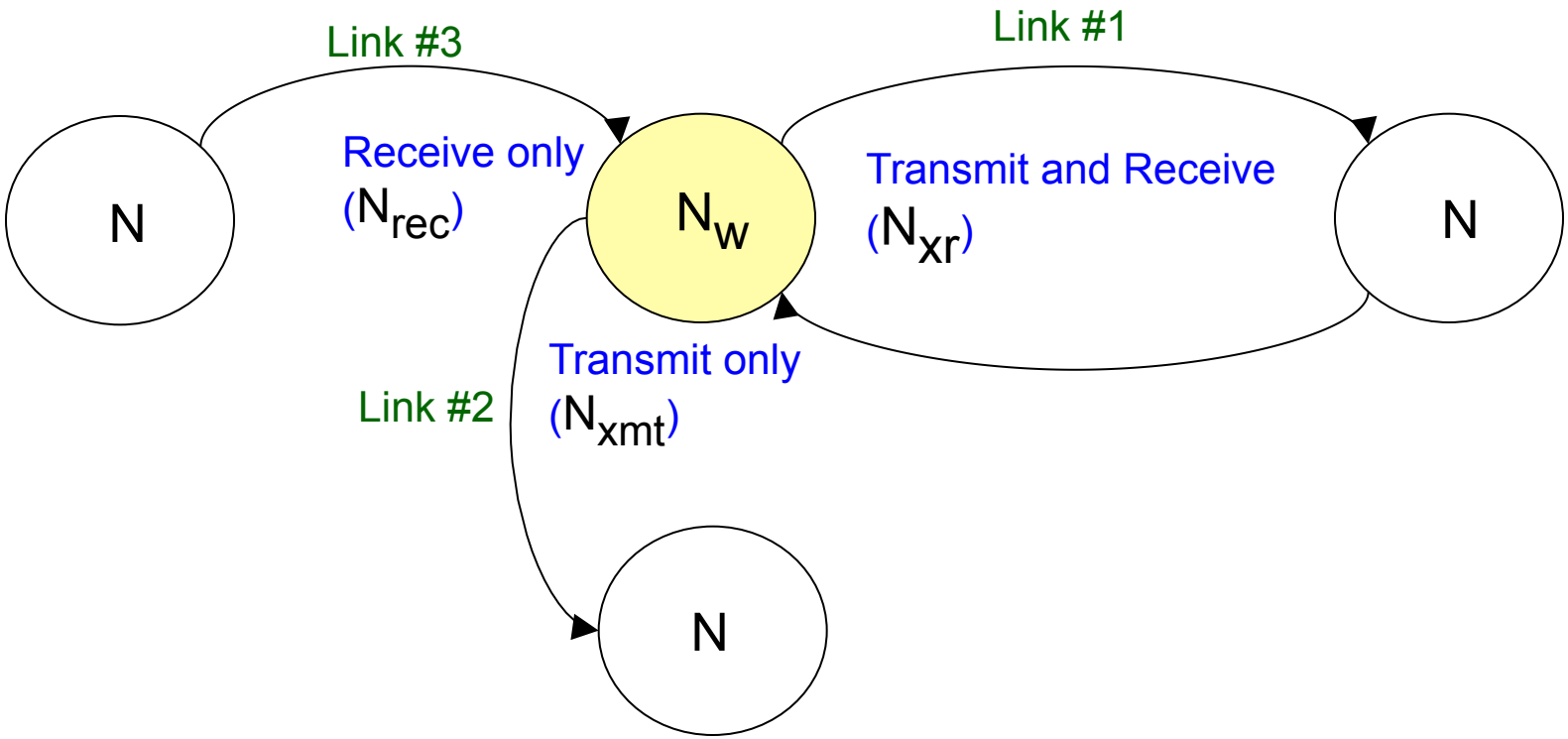
History – Acquisition Reform



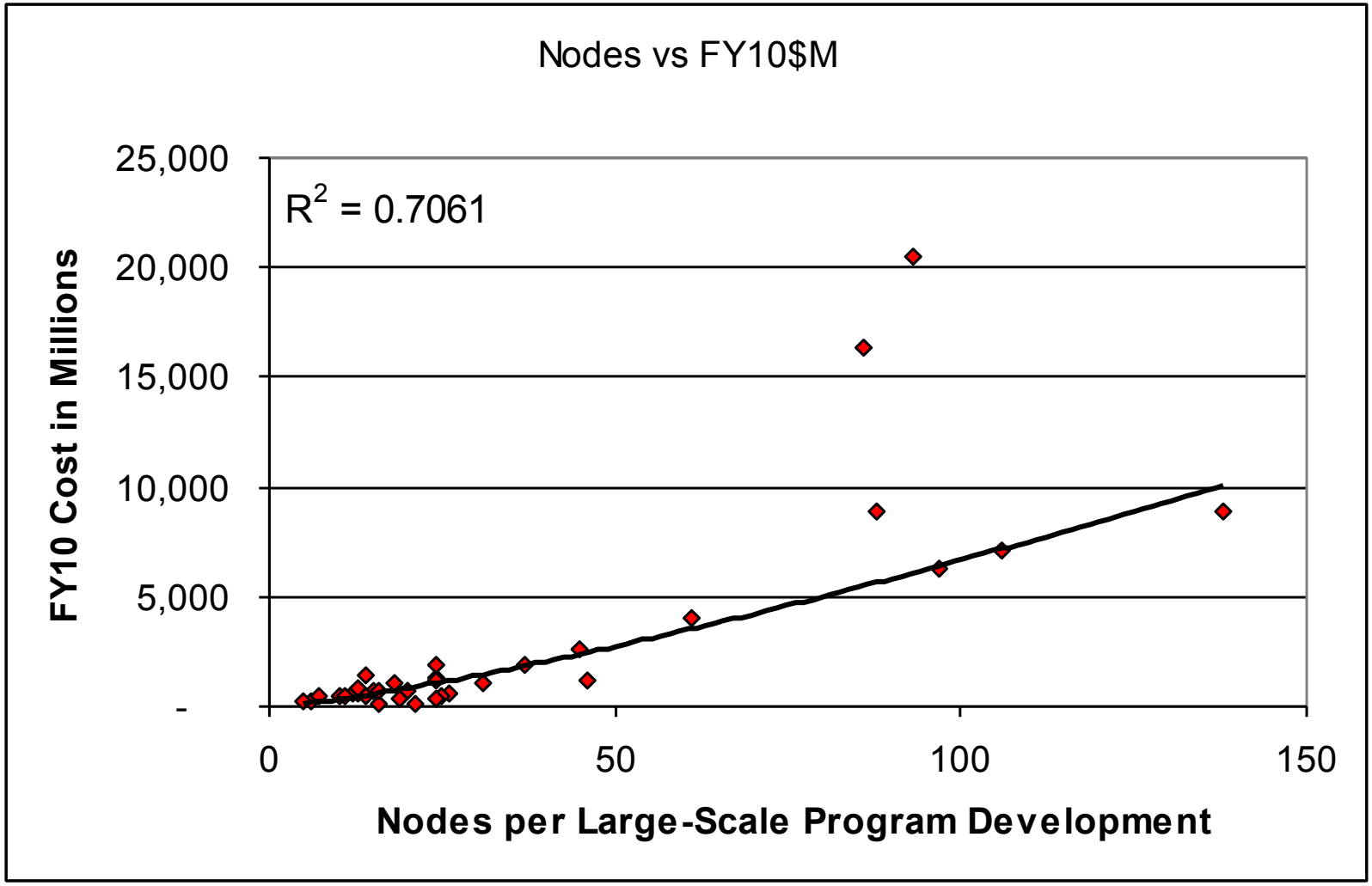
Example of Program Interoperability Mapping



Example - Interoperability

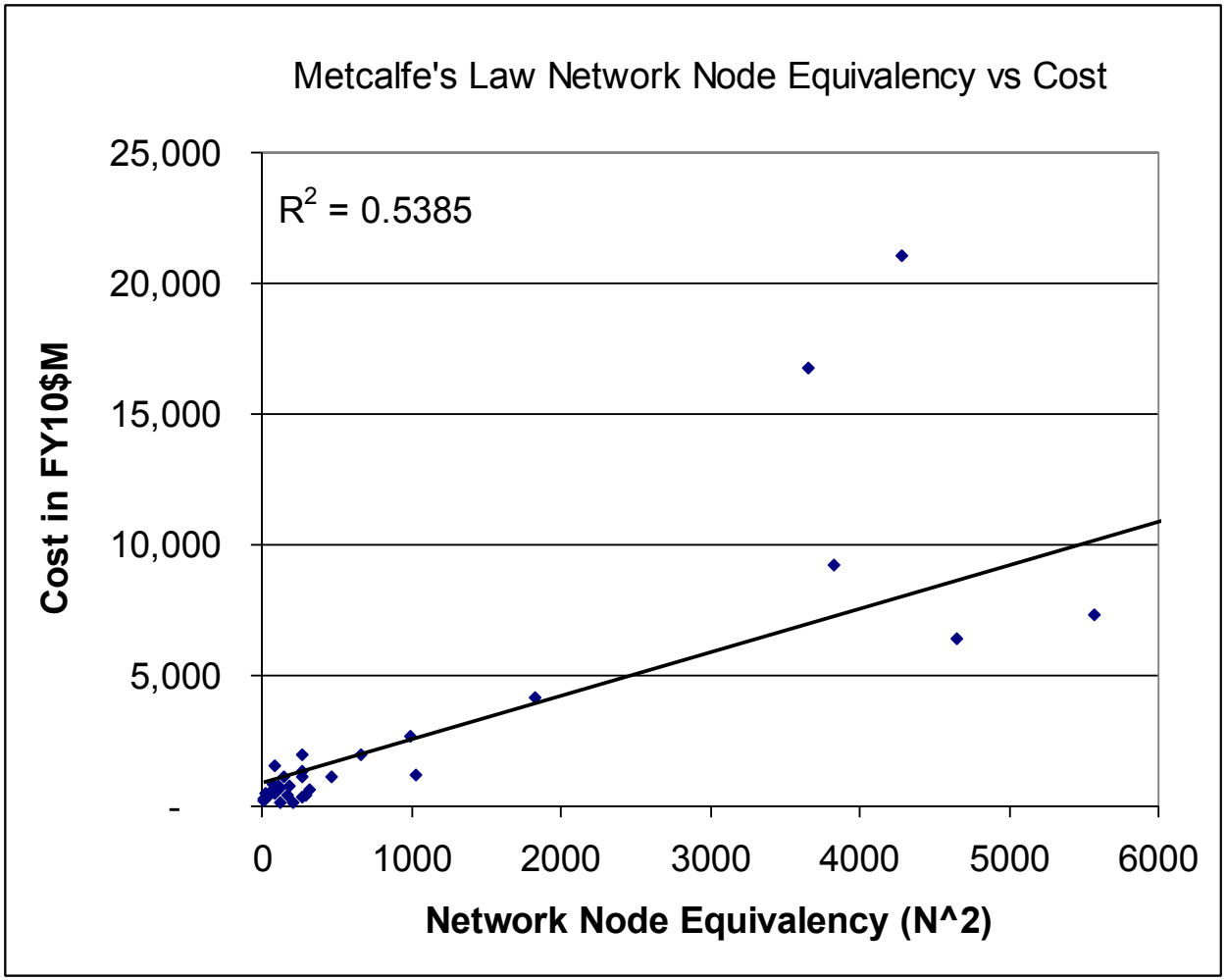


Analysis - Non-weighted Node vs. Cost

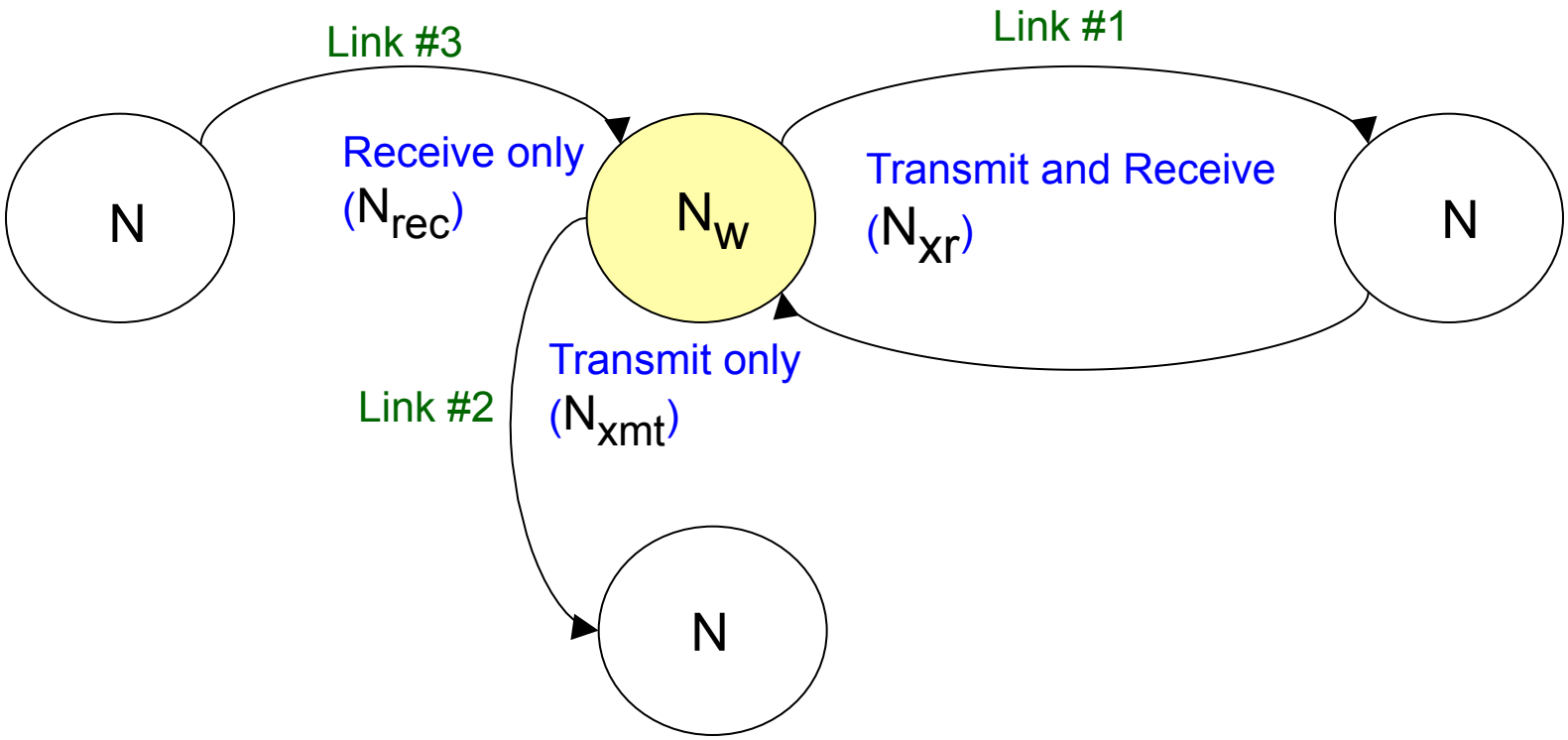


Analysis – using Metcalf's Law

- Law suggests that the value of a network is related to the maximum possible linkages among members of that network.
- Does not take complexity into consideration

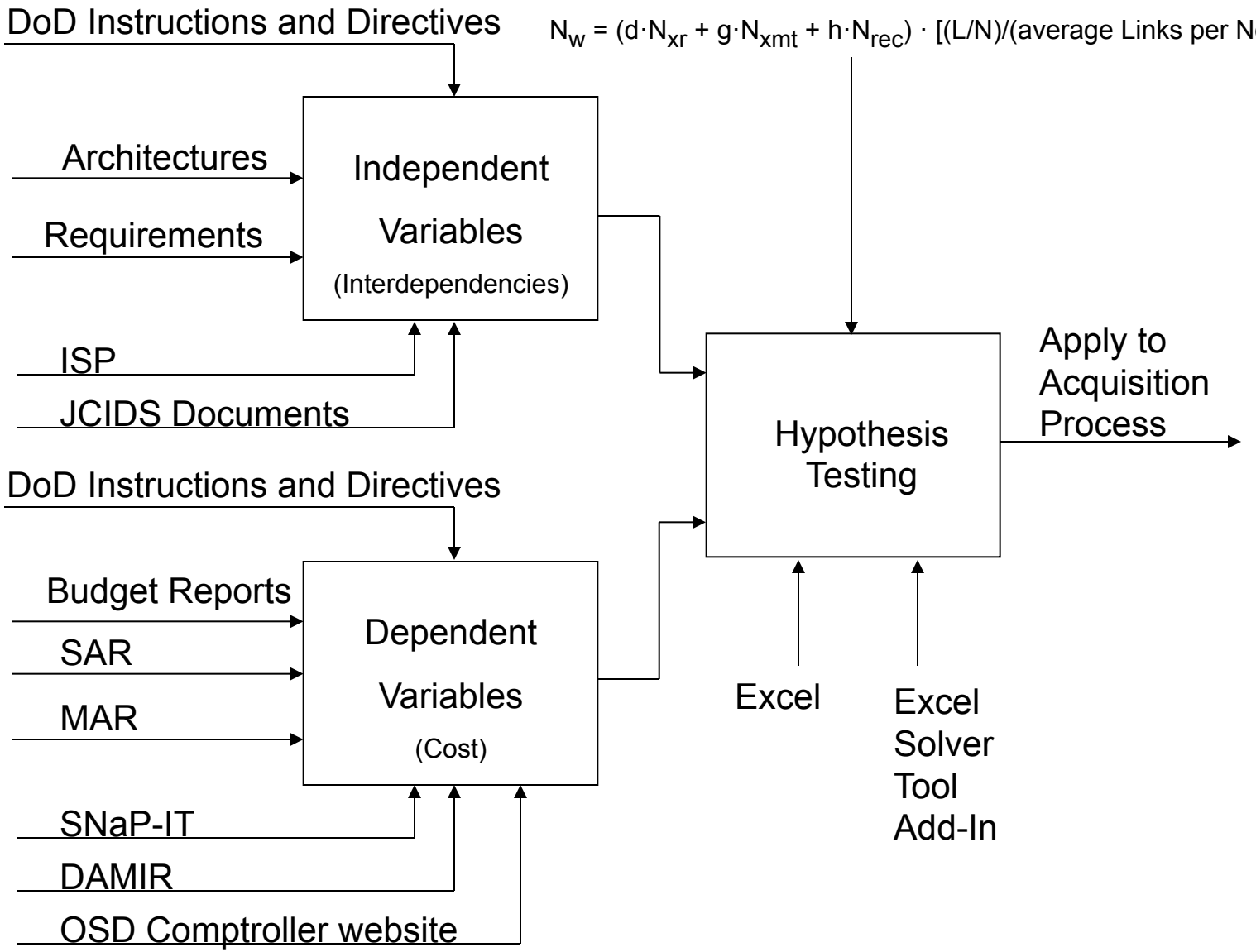


Formula (Weighted Nodes (N_w) formula to account for complexity)



$$N_w = (d \cdot N_{xr} + g \cdot N_{xmt} + h \cdot N_{rec}) \cdot [(L/N)/(\text{average Links per Node})]^e$$

Approach (how I am going about solving this problem)



Process – Calculate N_w (1 of 3)

Using Interdependence Data to assess a program's development cost

1. Obtain Architecture data for the subject program

2. Examine the System Data Exchange Matrix
   - Count the number of unique:
     - Transmitting Nodes (N_{xmt})
     - Receiving Nodes (N_{rec})
     - Transmit / Receive Nodes (N_{xr})
   - Count the number of Links per Node (Lt/Nt)

Process - Data Collection & Analysis (2 of 3)

Program Designator	Nodes					Links		Total	Weighted	L (total) / N (total)	N (weighted)	FY10$M
	Xmt&Rec (Nxr)	Xmt Only (Nxmt)	Receive Only (Nrec)	N (total)	Metcalf's Law (N^2)	Unidirectional	Bidirectional					
Program 1	61	11	21	93	4278	113	59	172	101	1.85	149	21,066
Program 2	80	7	1	88	3828	8	79	87	62	0.99	81	9,196
Program 3	60	23	23	106	5565	46	54	100	56	0.94	71	7,301
Program 4	10	39	12	61	1830	76	3	79	38	1.30	44	4,135
Program 5	15	8	14	37	666	22	14	36	23	0.97	22	1,945
Program 6	22	1	1	24	276	2	21	23	21	0.96	21	1,312

$$N_w = (1 \cdot N_{xr} + .5 \cdot N_{xmt} + .3 \cdot N_{rec}) \cdot [(L/N)/0.96]^{1.21}$$

Process – Cost (3 of 3)
(Large-Scale Program Complexity vs RDT&E Cost)

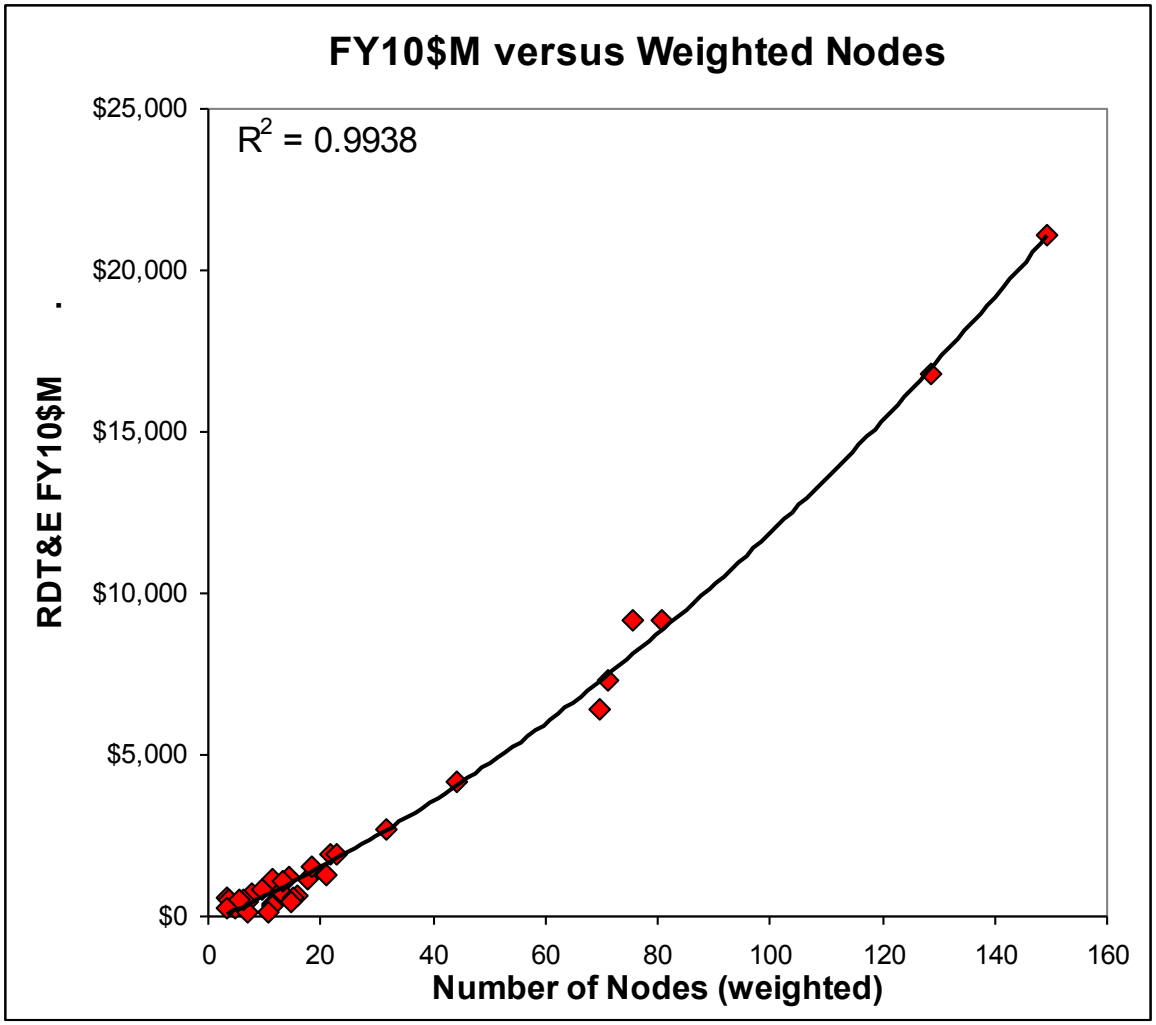
3. Fill the values into the equations

$$N_w = (1 \cdot N_{xr} + .5 \cdot N_{xmt} + .3 \cdot N_{rec}) \cdot [(L/N)/0.96]^{1.21}$$

4. For the dataset examined, excel spreadsheet calculated large-scale program acquisition cost associated with complex interdependent systems to be: $y = 20.749x^{1.3769}$, which equates to:

$$\$20.75M \cdot N_w^{1.3769}$$

Analysis – Weighted Nodes



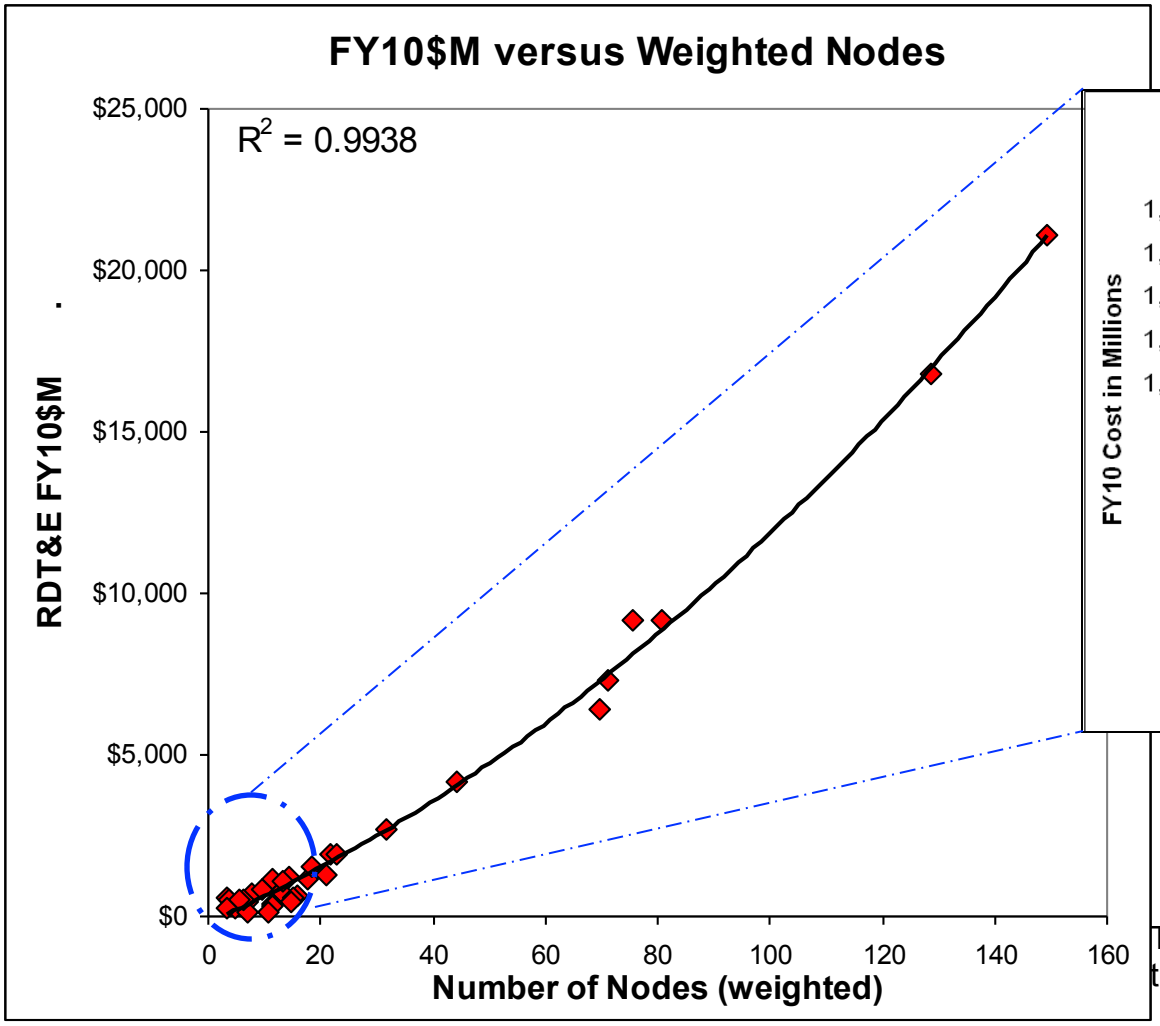
Summary

- The goal of the study was to identify and assess the effects of interdependence on U.S. DoD large-scale program developments and to apply these findings to assess cost risk to future programs.
  - The study focused on examining publicly released cost reports and interdependencies as interoperability as verified within program architectural views.

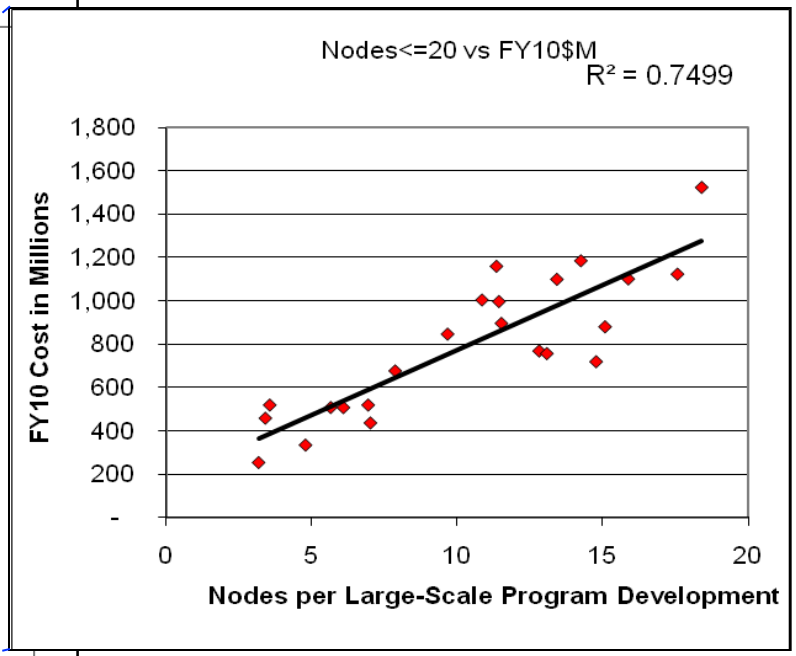
- Contribution to the field is in the development of an early cost estimation method based on the examination of legacy data from large-scale program developments with complex interdependent systems
  - The dataset will be applied to predict future developments with complex interdependency implementations

Questions

Analysis – Weighted Nodes



Expanded view of Nodes <= 20



This graph and equations below were derived from the analysis of 42 Large-Scale development