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Knowledge and Skills for Enterprise Transformation.

Simulation-Based Decision Support for Acquisition Policy and Process Design: The Effect of System and Enterprise Characteristics on Acquisition Outcomes

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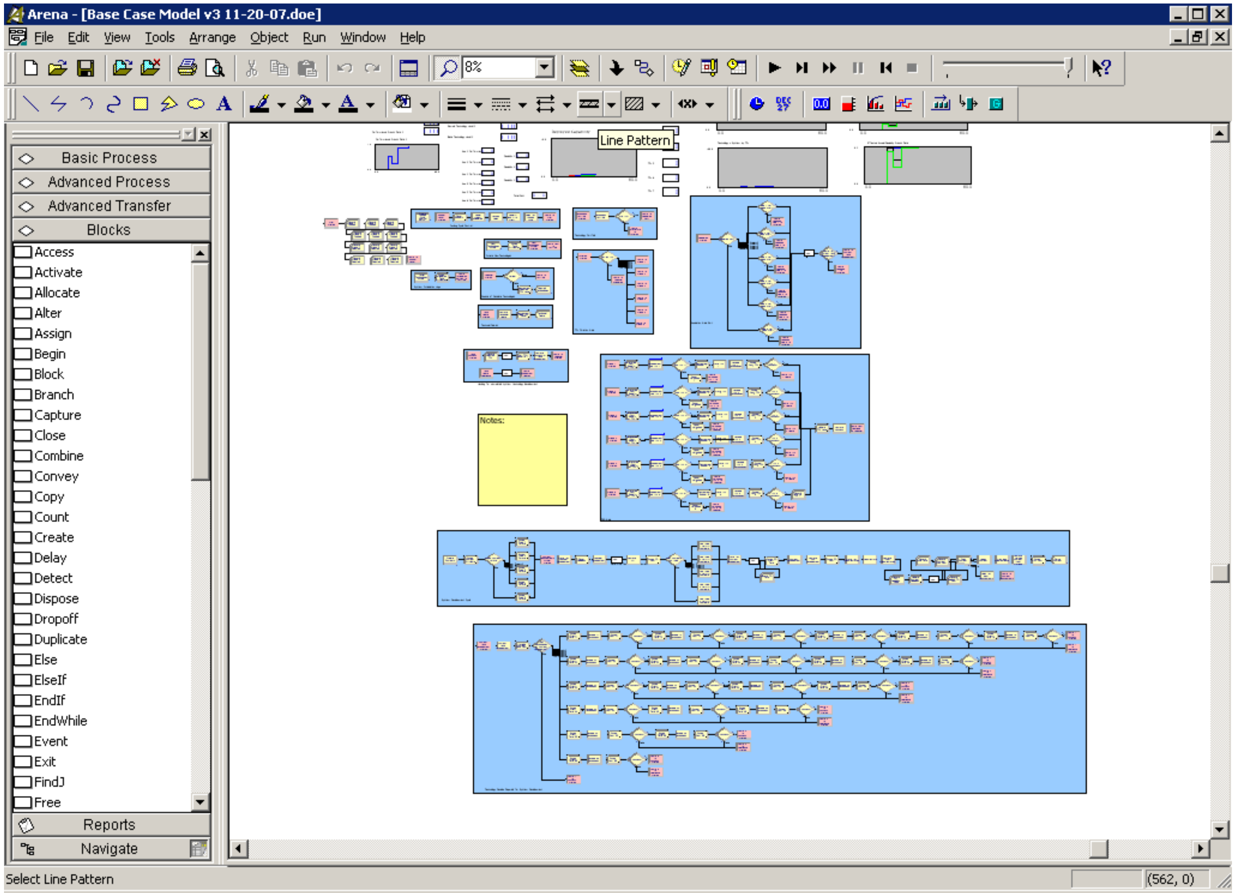
Agenda

- Motivation
- Previous work
- Modularity and sustainment models
- Experiment
- Results
- Future work

Motivation

- Previous findings indicate:
  - Evolutionary acquisition can result in faster deployment of capability
  - But may result in increased overhead cost due to more frequent acquisition cycles
- In general, what factors cause evolutionary acquisition to be more effective than traditional acquisition:
  - Lifecycle cost
  - Timeliness of deployed capability
  - Availability of new systems in the field
- In particular, what role does system modularity play:
  - Lifecycle cost
  - System availability

Existing Model



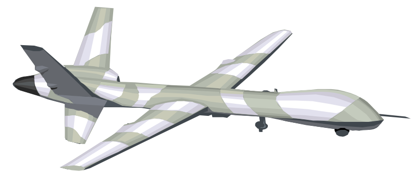
ARENA simulation model of acquisition enterprise

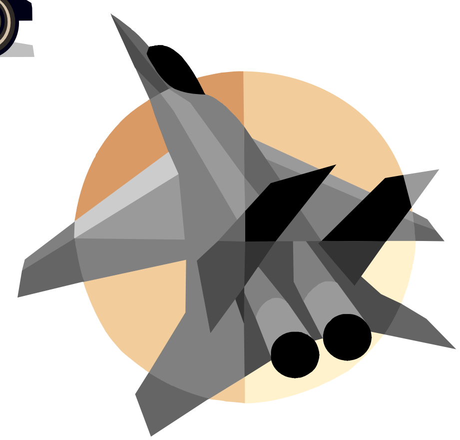
Model Summary

- Technical progress model
  - Addresses research exogenous to acquisition enterprise
  - Results are input to S&T model
- S&T model
  - Addresses maturation of technologies via a staged process
  - Incorporates technical risk
  - Assumes single S&T organization
- Acquisition model
  - Primarily addresses concept development, technology development, system development and production & deployment
  - Pulls technologies from S&T model

Modularity

- Independence of different system components
- Common infrastructure and standard interfaces
- Major principle in product and system design literature
  - Increased modularity decreases cost/time for repairs and technology upgrades in sustainment
  - Increased modularity increases cost of design
  - Increased modularity may increase costs for changes to infrastructure





Modularity Model

1	0.1	0.4	0.5	1
0.4	1	0.3	0.3	0.2
0.2	0.3	1	0.6	0.9
0.7	0	0.5	1	0.5
1	0.5	0.3	0.3	1

- Systems consist of components or modules (i.e., collection of components)
- A relationship between components i and j exists if changes to i causes changes to j
- Assume this relationship is characterized by a probability that a change to i causes a change to j
- Modularity can be represented as a matrix
- This matrix is not necessarily symmetric
- Diagonal elements are not relevant

Modularity Examples

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Completely modular

1	0	0
0	1	0
0	0	1

Weak connections

1	0.5	0.5
0.5	1	0.5
0.5	0.5	1

Few connections

1	0	1
0	1	0
0	0	1

Completely non-modular

1	1	1
1	1	1
1	1	1

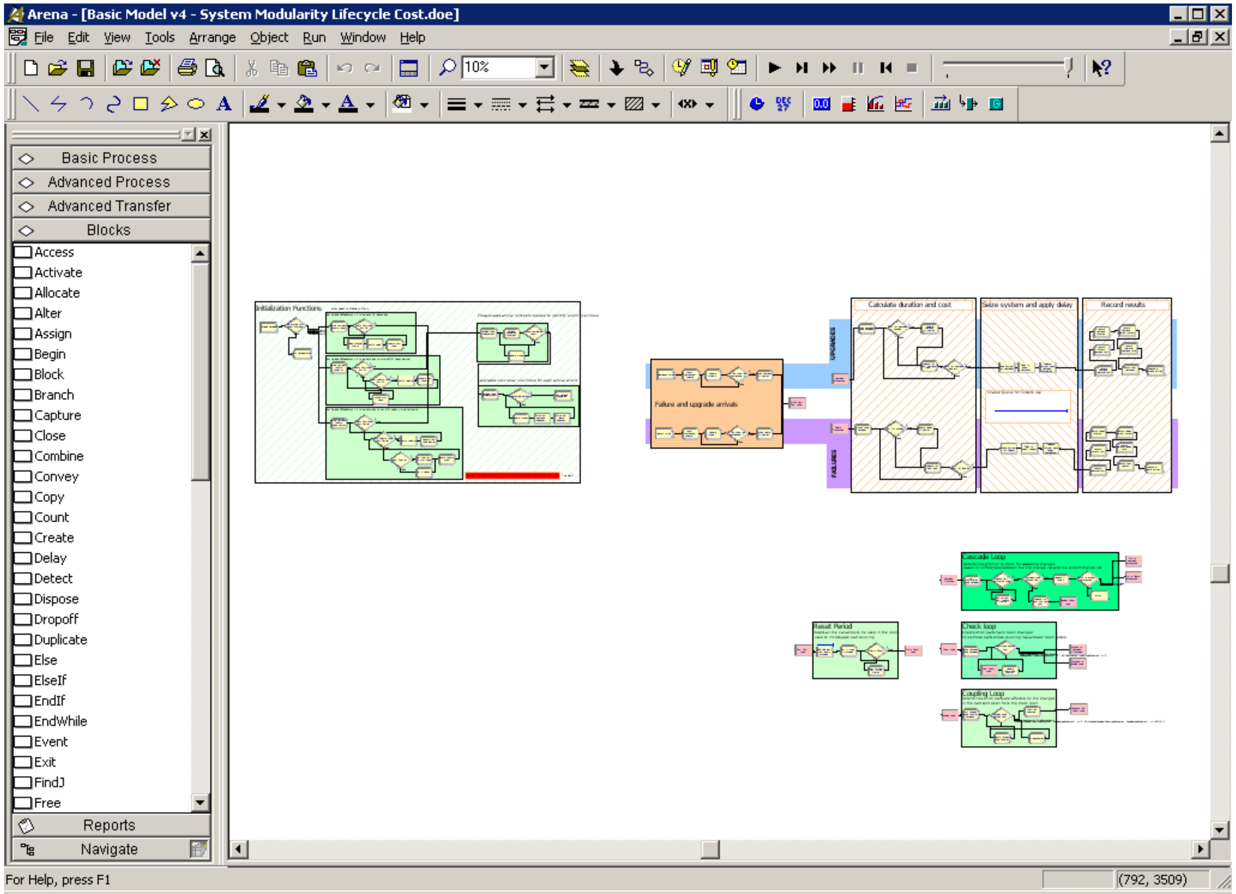
With infrastructure

1	1	1
0	1	0
0	0	1

With modules

1	1	0	0
1	1	0	0
0	0	1	1
0	0	1	1

Sustainment Model



Model Summary

- Addresses repairs and technology upgrades for systems in the field
- Each failure or technology upgrade affects only one component
- But due to relationships, failures and technology upgrades can affect other components
- Failures and technology upgrades are assumed to occur via a Poisson process

Sustainment Parameters

- f_i is the failure rate associated with component i. f_1 is undefined when infrastructure is present (since infrastructure is component 1).
- r_i is the repair rate associated with component i. r_1 is undefined when infrastructure is present.
- t_i is the arrival rate of new technology upgrades for component i. t_1 is undefined when infrastructure is present.
- u_i is the upgrade rate for component i. u_1 is undefined when infrastructure is present.
- p_i is the cost of repairing component i. p_1 is undefined when infrastructure is present.
- q_i is the cost associated with a technology upgrade to component i. q_1 is undefined when infrastructure is present.
- c_{ij} is the compatibility cost associated with making component j technologically compatible with component i if i is upgraded, and if the interaction between i and j necessitates that j be made compatible to the new technology for i. c_{i1} is undefined when infrastructure is present.

Parameter Values

- Matrix has 10 components
  - Adjusted to 16 for systems with modules
- f_i = 60 days for all i
- r_i = 1 hour for all i
- t_i = 360 days for all i
- u_i = 6 hours for all i
- p_i = 10 currency units for all i
- q_i = 100 currency units for all i
- c_{ij} = 15 currency units for all i and j

Experiment

- Independent variable – relationship values within a class of modularity matrix types
  - Relationship Strength (Type 1) - All non-diagonal matrix elements have the same probability value (this value ranges from 0 to 1)
  - Relationship Number (Type 2) - All non-diagonal matrix entries are either 0 or 1 (number of 1's determined randomly by probability ranging from 0 to 0.6)
  - Modules (Type 3) - Matrix is composed of modules of varying size (number of modules ranges from 1 to 16)
- Dependent variables – repair costs, upgrade costs and system availability
- Time horizon – 10 years of system operation

Independent Variables

Relationship Strength

1	0.5	0.5
0.5	1	0.5
0.5	0.5	1

Vary all entries between 0 and 1

Relationship Number

1	0	1
0	1	0
0	0	1

Vary number of entries (all equal to 1)

Modules

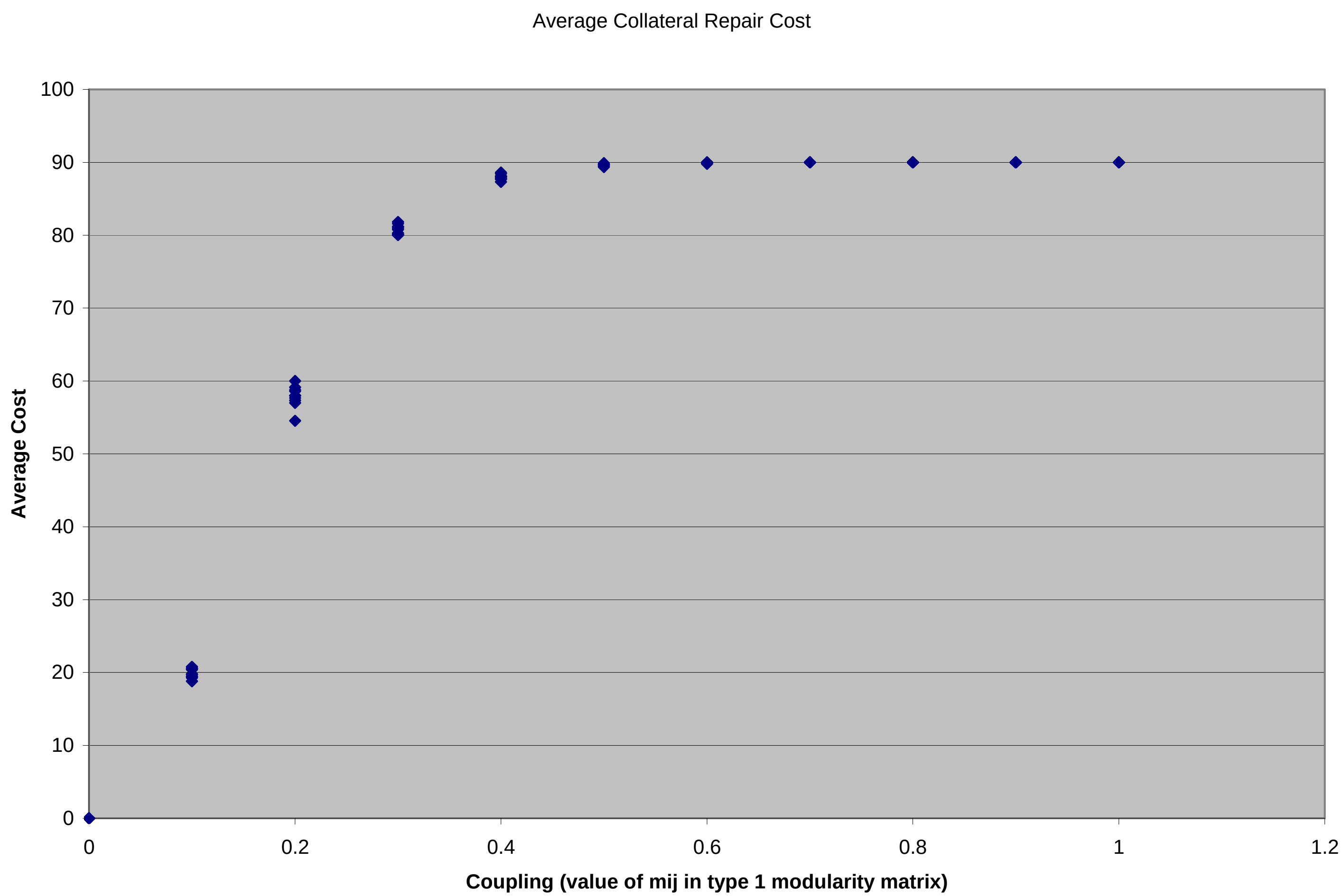
1	1	0	0
1	1	0	0
0	0	1	1
0	0	1	1

Vary number and size of modules

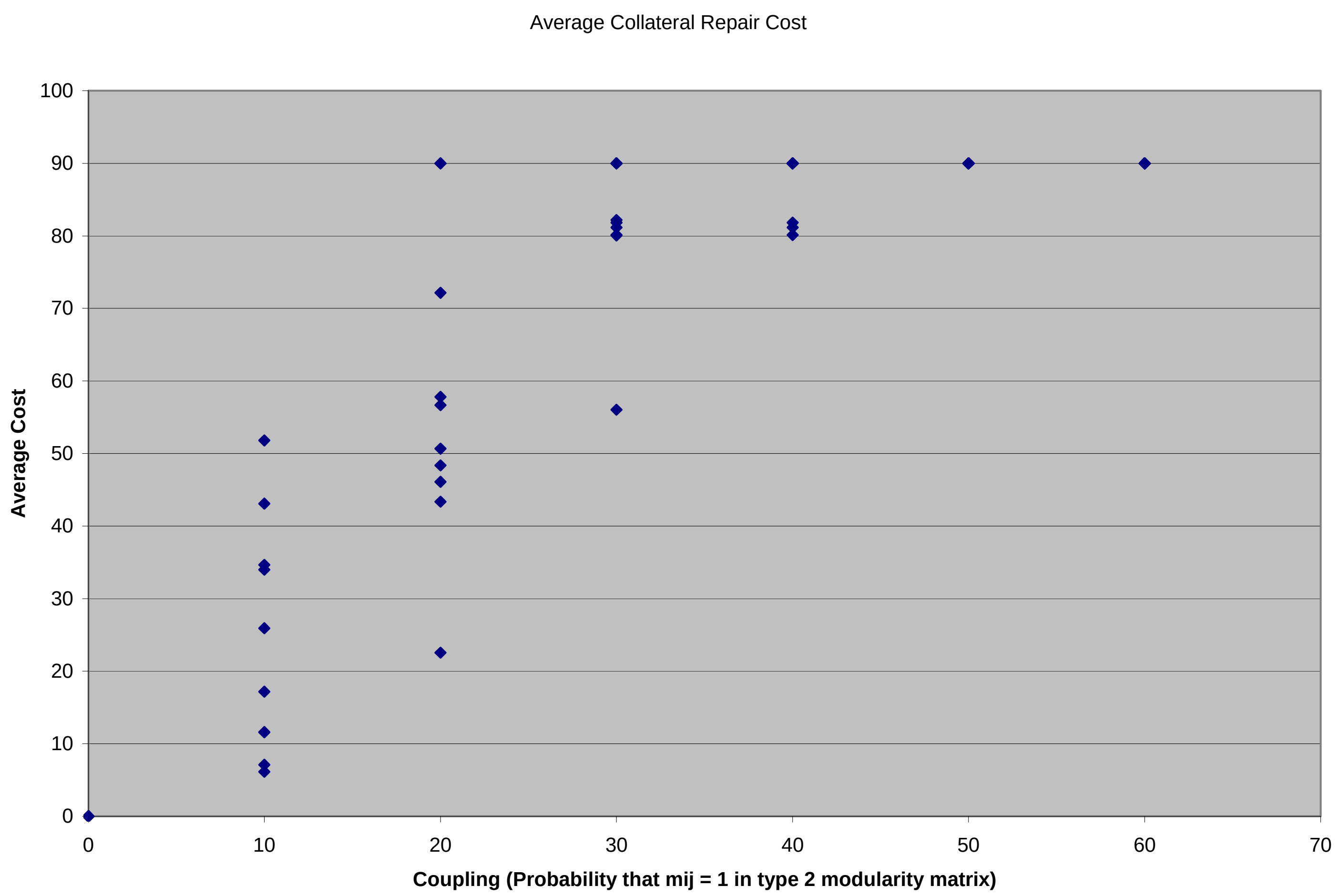
Results Summary

- Major cost benefits for high levels of modularity, with diminishing returns as modularity decreases
- Systems with varied number of strong relationships exhibit greater cost variability than those with varied strength of relationships
- Systems with modules (as opposed to components) exhibit a linear cost effect (increasing cost as module size increases)
- Availability exhibit similar behavior (with more variability)

Repair Cost – Strength

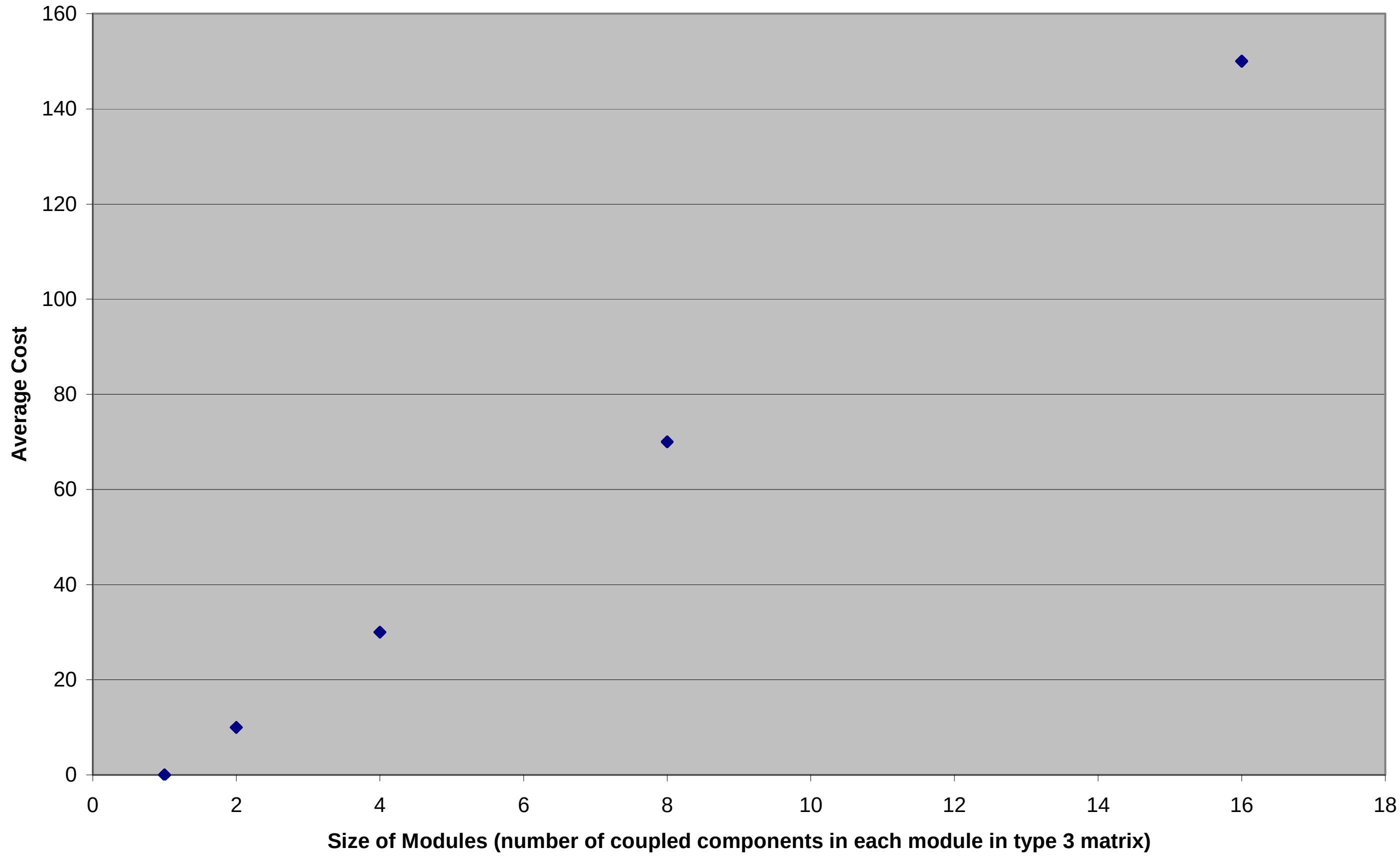


Repair Cost – Number

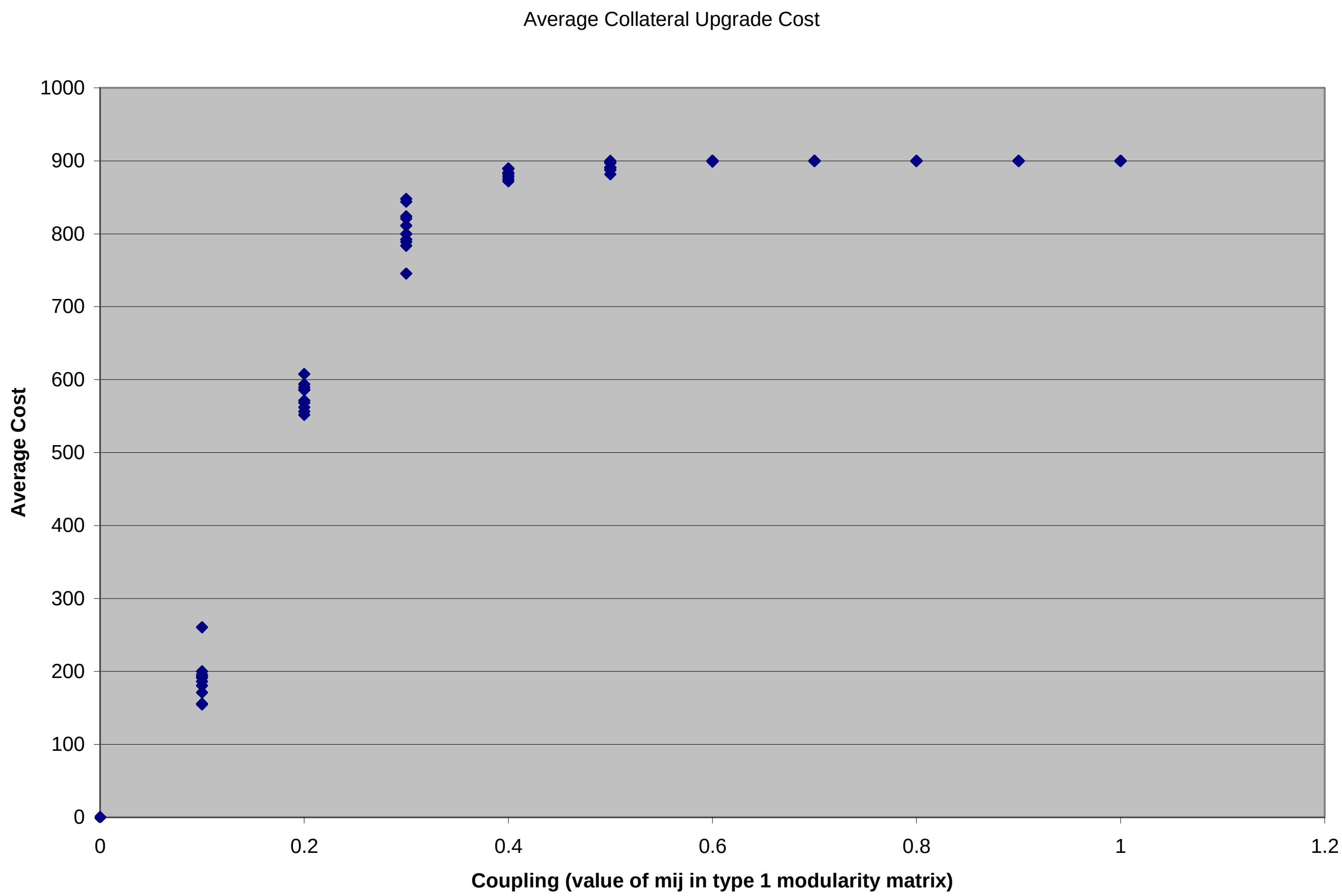


Repair Cost – Modules

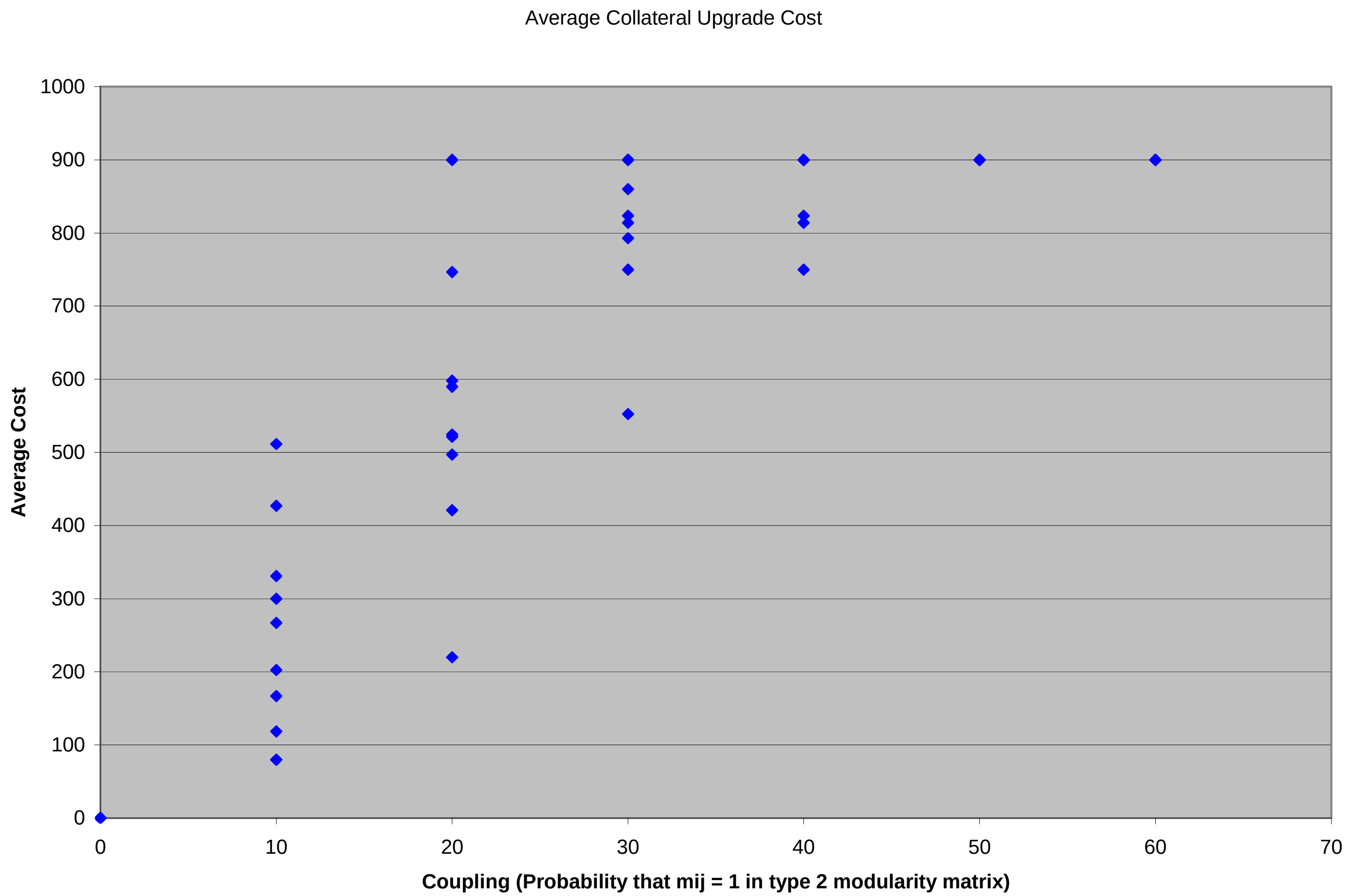
Average Collateral Repair Cost



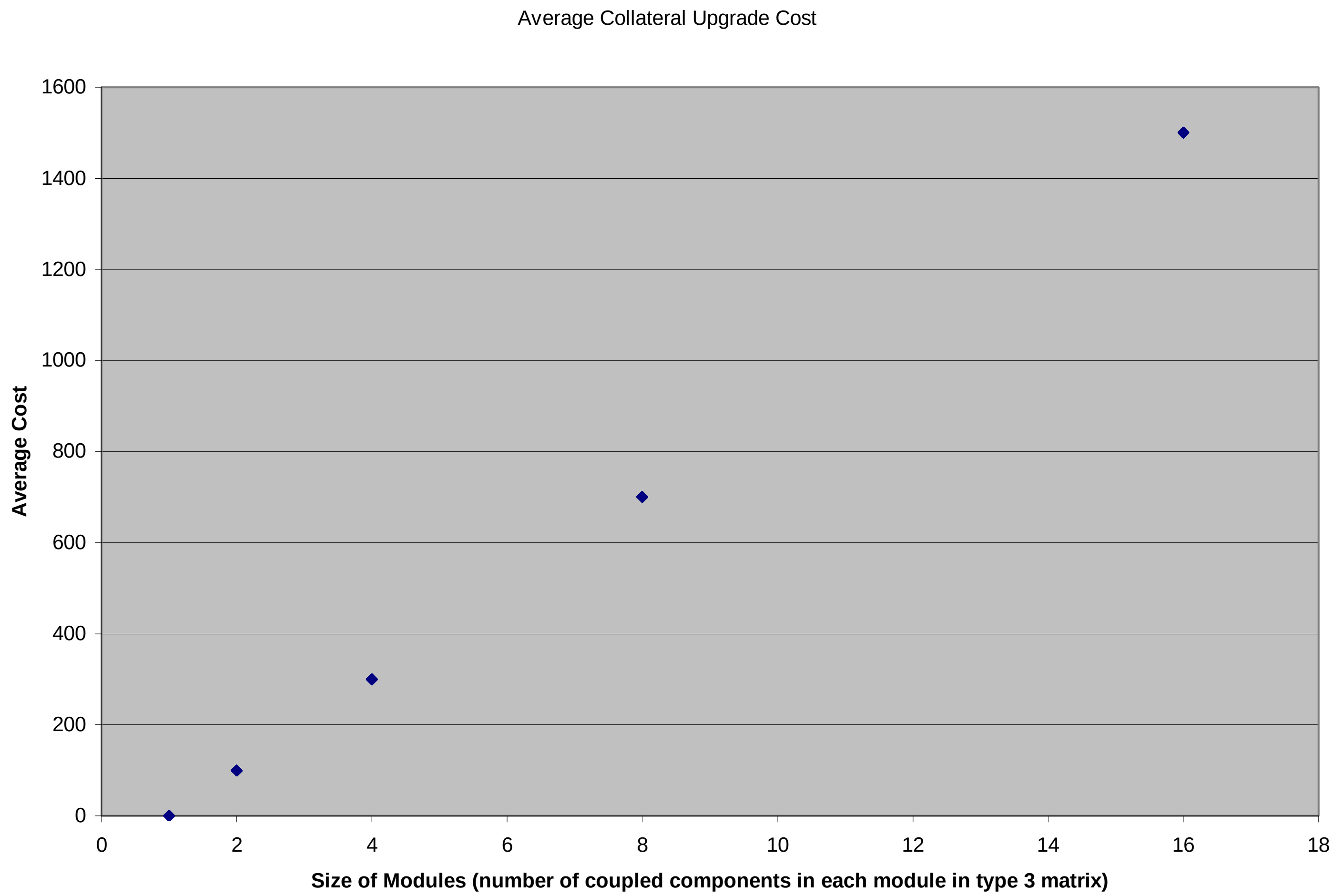
Upgrade Cost – Strength



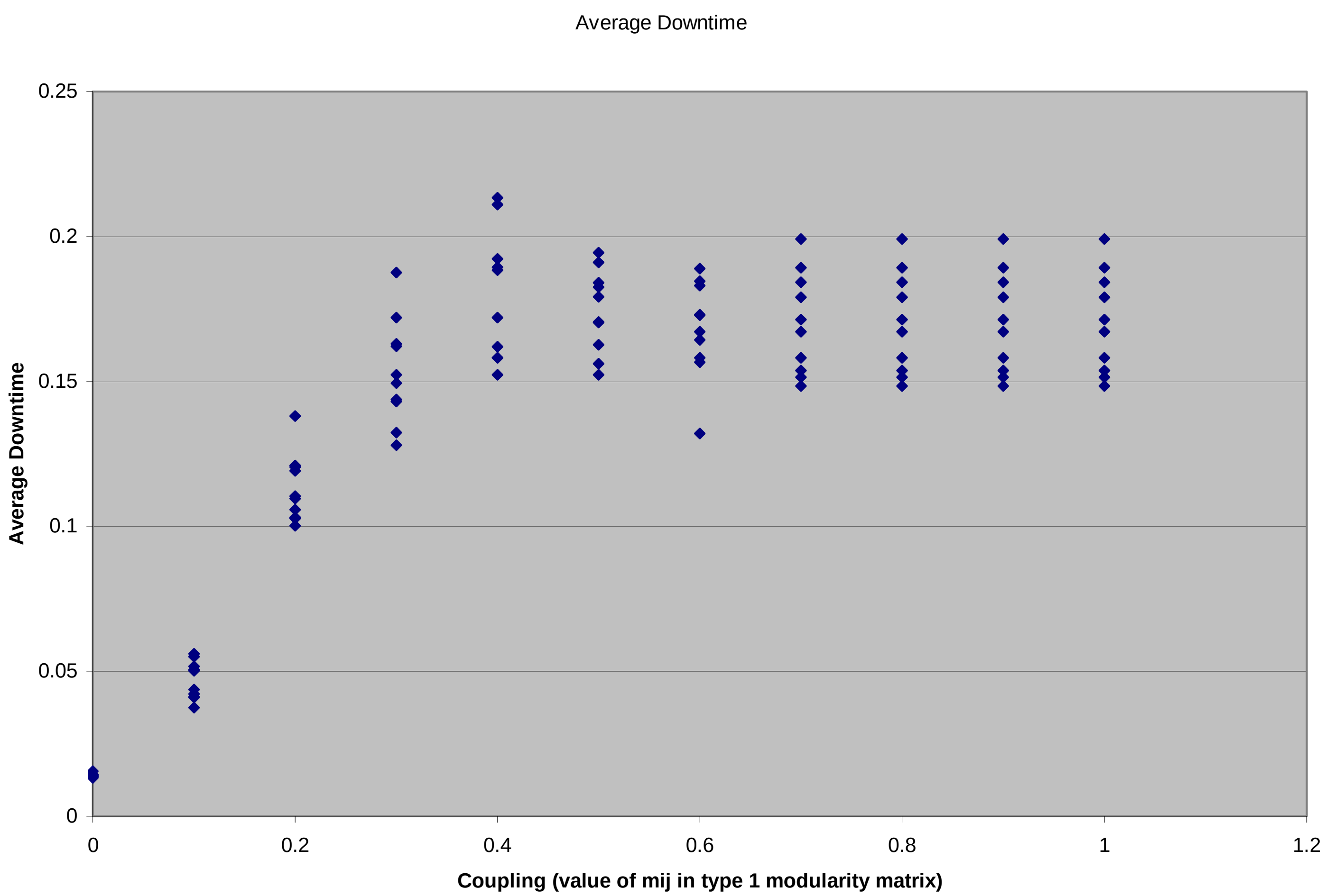
Upgrade Cost – Number



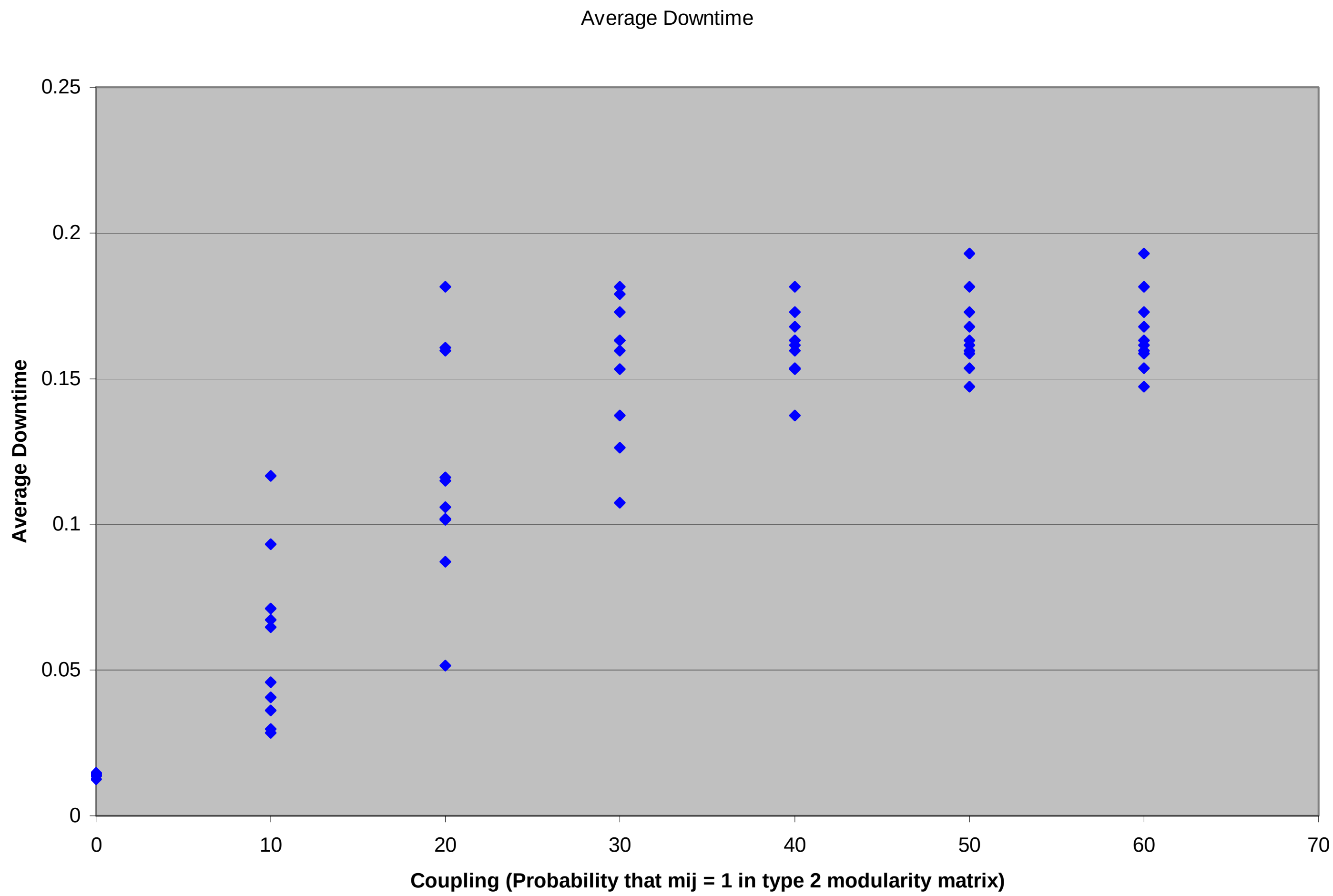
Upgrade Cost – Modules



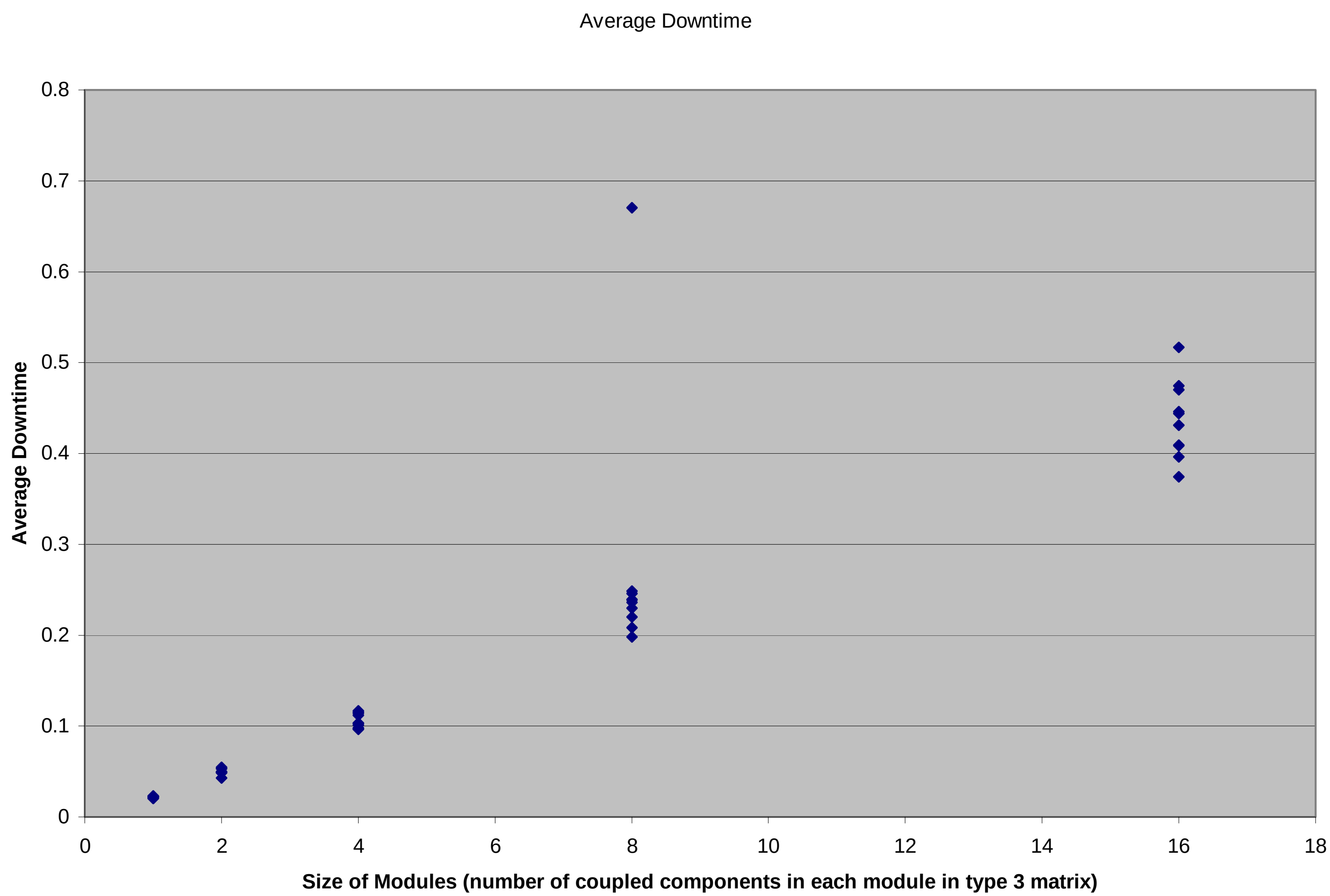
Availability – Strength



Availability – Number



Availability – Modules



Conclusions

- Models developed to study effect of system modularity in sustainment
- Simulation experiments demonstrated effects of different patterns of modularity in terms of
  – Repair costs
  – Technology upgrade costs
  – System availability

Future Research 1

- Develop a model of engineering costs for design and development and production of modularity in systems
  - Study trade-offs between design/development and sustainment costs and availability
- Characterize modularity via a standardized modularity index
  - Aid in categorization and experimentation
- Integrate sustainment model with existing acquisition model to support analysis of effectiveness of evolutionary acquisition with regard to
  - Mission risk
  - S&T alignment and funding strategy
- Analyze real systems with this framework
  - UAS and JSF

Future Research 2

- Move beyond process-oriented representations to incorporate organizational behavior
  - Human behavior via character models
  - Social and organizational networks
  - Eco-system
  - Organizational stories via drama management
- Use organizational simulation to study role of incentives and information in acquisition enterprise performance

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