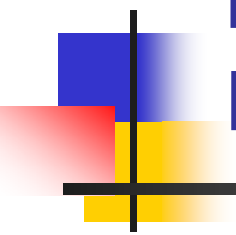
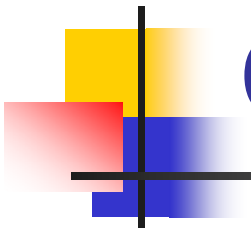


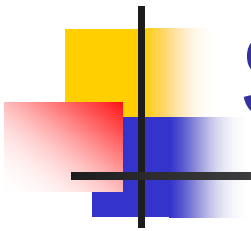
Architectural, Development Lifecycle, and Programmatic Considerations of Hyperexponential Change

John Georgas
The Aerospace Corporation
Institute for Software Research (UCI)



Outline

- **Software Architecture**
- Hyperexponential Change
- Raging Incrementalism
- Raging Incremental Development
  - Architectural Principles
  - Lifecycle Considerations
  - Programmatic Considerations
- Example: Launch Range Video
- Summary

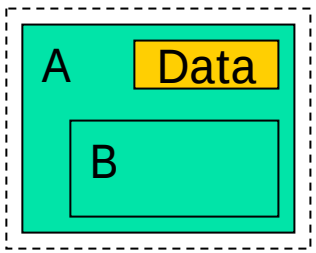


Software Architecture

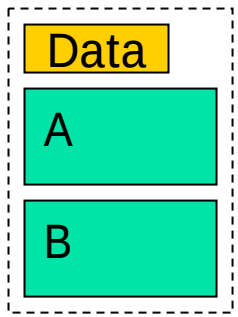
- Structures of architectural elements.
  - Components (and their parameters).
  - Interconnections (preferably explicit).
- Software architecture promises systems that are easier to understand, build, maintain, and analyze.
- Software architecture is about *composition*.
  - Composing elements to achieve system goals.
  - Focus on *architecting*, rather than *building*.
  - High-level view of systems; not getting mired in the low-level implementation details.

System Composition

- Not all architectures are created equal.
  - *When* and *how* are components bound?
    - Early and late binding.
    - Static and dynamic binding.
  - Often, these issues are addressed by *architectural styles*.
  - *Late* and *dynamic* binding are ideal.
- Just some examples:

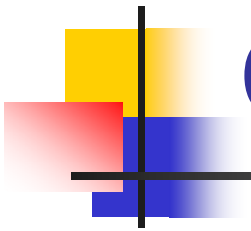


One component subsumes another.



Components share a common data store.

Remote components exchange data.



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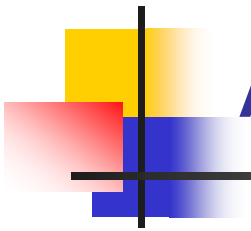
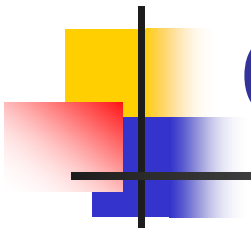
Accelerating Change

- Examine the rate of change of change.
- Trends show:
  - Exponential improvement in rate of change and doubling periods.
  - By 2025, 100 years of 90's type progress.
  - By 2101, 20000 years of 90's type progress.
- The result is *hyperexponential change*.
- Everything changes...
  - "Everything you knew yesterday is wrong today."
  - The system you've just designed is already obsolete.



Architectural Requirements

- *Late binding* of components.
  - As far away from source code composition as possible.
- *Dynamic binding* of components.
  - Bindings that are changeable at runtime.
- *Embracing change* through appropriate architectural methodologies and techniques.



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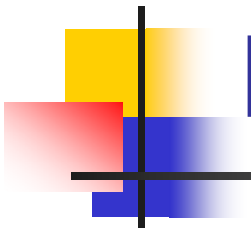
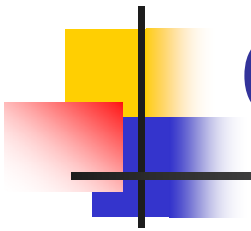


Raging Incrementalism

- System engineering based on:
  - Components (*bricks*) made of:
    - Commodity hardware piece-parts.
    - Open-source software.
  - Interconnections through:
    - Protocols-based interaction.
    - REpresentational State Transfer (REST) architectural style.



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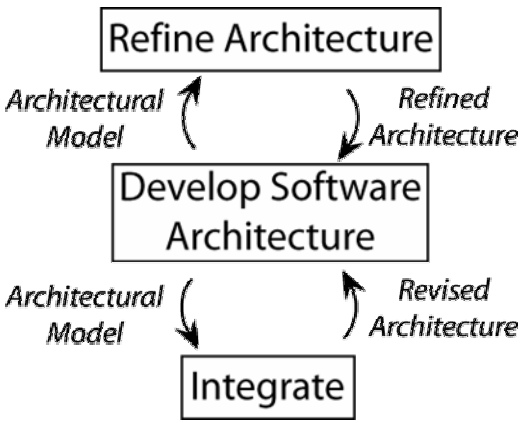
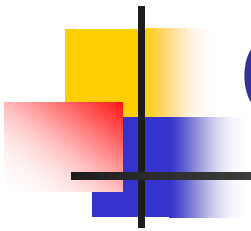
Architectural Principles



- Naturalistic architectural design.
  - Based on “naturally occurring” materials.
  - Architecture “grown” from these materials.
  - *Architect* around the building blocks, rather than building around the architecture.
  - Continually evolving entity.
- Explicit architectural model description.
- Based on REST architectural style.
  - Independent components.
  - Stateless interactions.
  - Components modeled as *resources* with their own *namespace* (which may expand).
  - Late and dynamic binding.
    - Interconnections using URI addressing.



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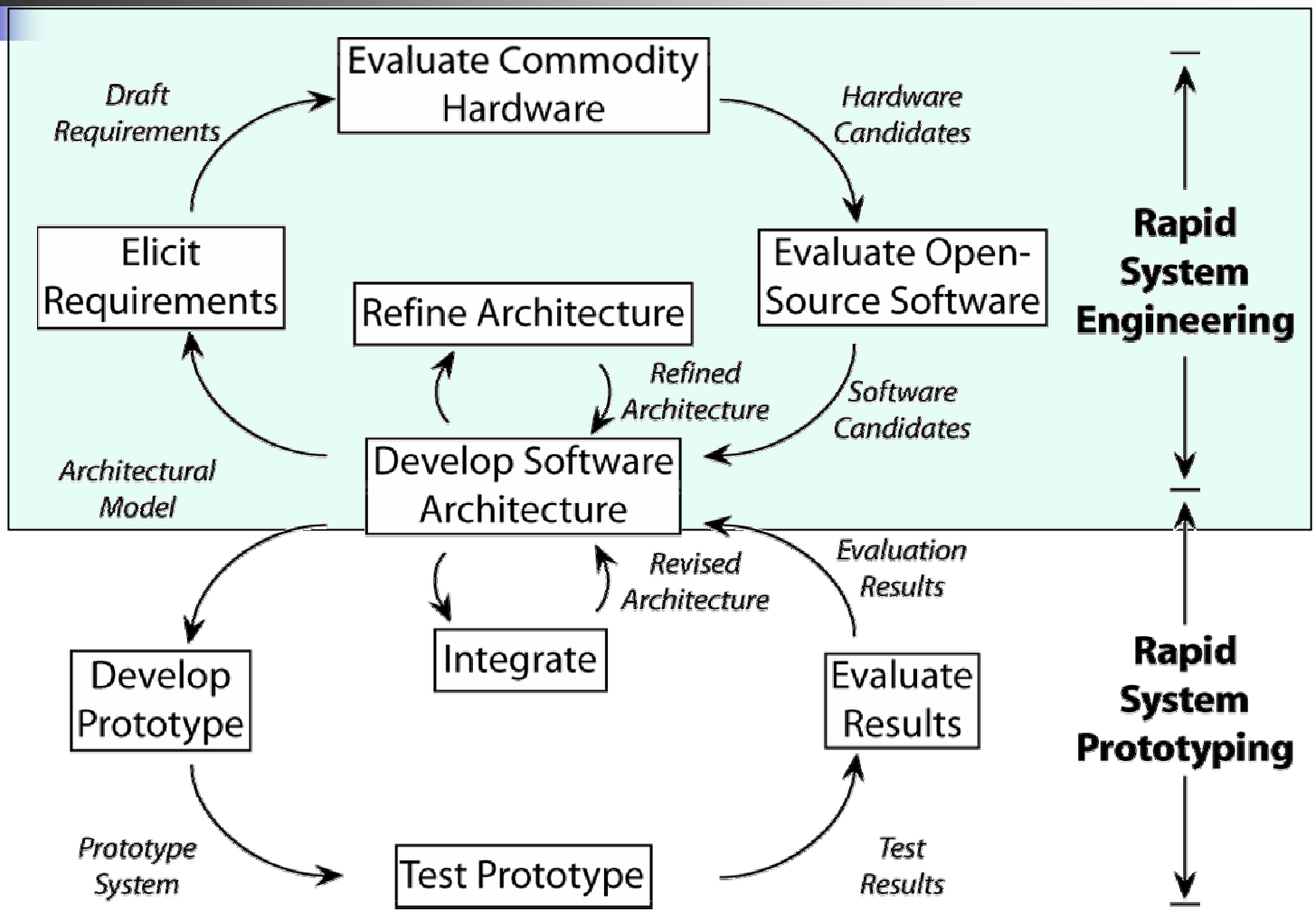
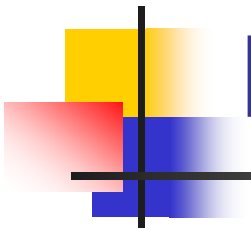
Lifecycle Considerations

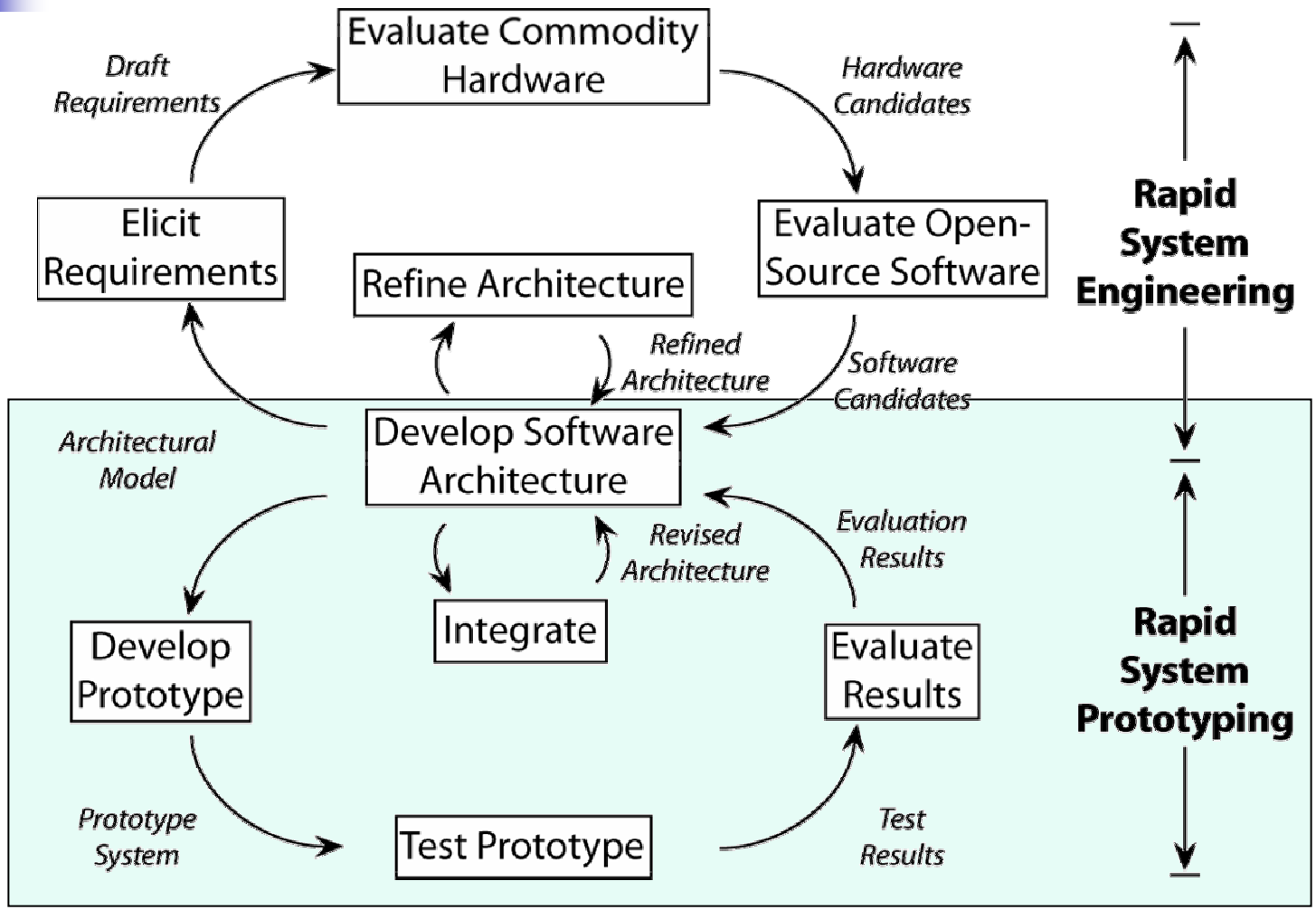


Rapid System Engineering

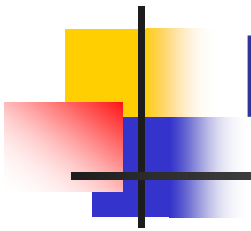


- Elicit Requirements
  - System requirements, as understood at the time.
- Evaluate Commodity Hardware
  - Cheap, non-specialized, easily replaced, hyperexponentially improving.
- Evaluate Open-Source Software
  - *Free* (in more ways than one), diverse.
- Architect
  - Architecture may be refined or revised due to:
    - Increased requirements understanding.
    - New hardware/software components.

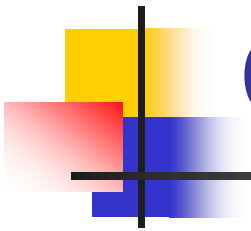
Lifecycle Considerations



Rapid System Prototyping



- Develop Prototype
  - Rapidly developed.
  - Relative to effort, extremely fully-featured.
- Test Prototype
- Evaluate Results
- Architect
  - May be refined or revised due to:
    - Insight gained during prototyping.
    - Failure to meet goals/requirements during testing.



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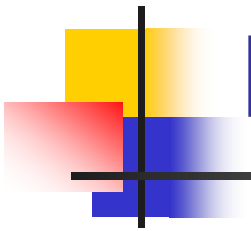
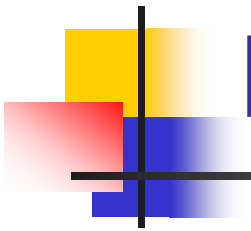


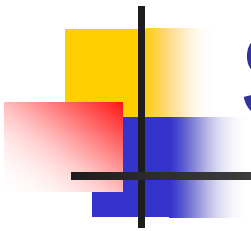
Development Cycles

- Measured in *weeks* and *months*, not years.
  - A few months (at the most) for an initial iteration resulting in a complete prototype.
  - Weeks for further iterations resulting in revisions and refinements.
- Independent and parallel modification of components.
  - Promoted through decoupled RESTful interactions.
- Shorter cycles result in less management overhead.
  - Promote early incorporation of lessons-learned.



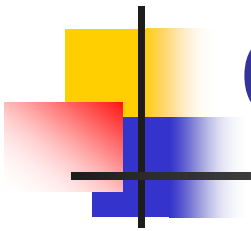
Productivity

- Development focused on *integration*, not coding.
  - Conventional productivity measures (LOC, function points) inappropriate in this context.
- Measures and project milestones focused on:
  - Scale of integrated components.
  - Functionality achieved.
- Focus on quality, not quantity.



Staffing

- Exceptional *architects* and *integrators* take precedence over programmers.
  - Development focuses on integration, rather than “in-house” development.
- Special role – *software surveyor*
  - Knowledge of open-source projects – both existing, and planned.
  - Aware of strengths and weaknesses of projects, as well as dependencies and requirements.
  - This knowledge is essential:
    - Formulates early prototype systems.
    - Enables and guides long-term planning.



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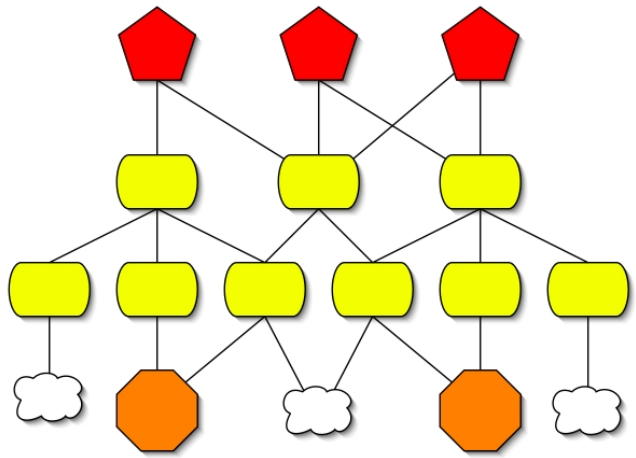
RAnge Video Experiment

- Experimental replacement for video monitoring at Eastern and Western launch ranges.
- Features:
  - Large-scale, distributed system.
  - Real-time video encoding and decoding.
  - Video archival.

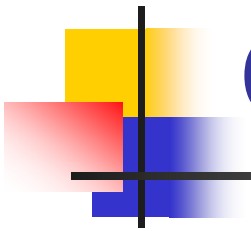
Raging Incremental Prototype

- Peer-to-peer architecture.
- RESTful interactions.
- Developed in a 6 week cycle.
- Video Camera Brick:
  - Shuttle PC with Firewire camera.
  - Network camera control.
  - Software-based MPEG-4 encoding.
  - Precision timestamps for video frames.
  - Digital video streaming.
- Video Proxy Brick
  - Custom Python program.
  - Live.com streaming libraries.
- Video Distribution Server Brick
  - Based on open-source Darwin Streaming Server from Apple.
- Video Archive Brick
  - 4U commodity rack server containing 4 terabytes of storage.
  - FreeBSD.



Components Used

- Video Camera Brick
  - Hardware
    - Shuttle form-factor box.
    - Unibrain Firewire camera.
  - Software
    - Debian Linux OS (open source).
    - libdc1394 (open source).
    - spook broadcaster (open source).
    - xViD MPEG4 encoding (open source).
- Video Distribution Brick
  - Hardware
    - Shuttle form-factor box.
  - Software
    - Debian Linux OS (open source).
    - Darwin Streaming Server (open source).
- Video Archive Brick
  - Hardware
    - 4U commodity rack server (4 TB).
  - Software
    - FreeBSD OS (open source).
    - mencoder MPEG4 encoder (open source).
    - mplayer for video playback (open source).
    - MySQL database (open source).
- Video Proxy Brick
  - Hardware
    - Shuttle form-factor.
  - Software
    - Custom Python video proxy.
    - Live.com RTP/RTSP libraries (open source).
- Protocols
  - RTSP, RTP, HDP, HTTP, TCP.
- Standards
  - IEEE1394.
- Languages
  - C, C++, Python.



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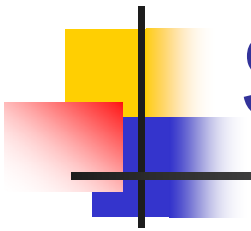

Summary

- Hyperexponential change changes everything.
- Raging incrementalism
  - Architecture must be about composition.
  - Late and dynamic component binding.
- Formulations of architectural principles, development lifecycle, and programmatic insight.
- Proof-of-concept prototype in the RAnge Video Experiment (RAVE) system.

What We Learned…

- Success comes at a price.
  - Tangible results rest on a mountain of failure.
- Going at it alone can hurt.
  - Walk a fine line between asking for help and being self-sufficient.
- Flexible and understanding management is the key to happiness.