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*Synthetic  
Theater  
Operations  
Research  
Model*



**IMC, Inc.**  
Innovative Management Concepts

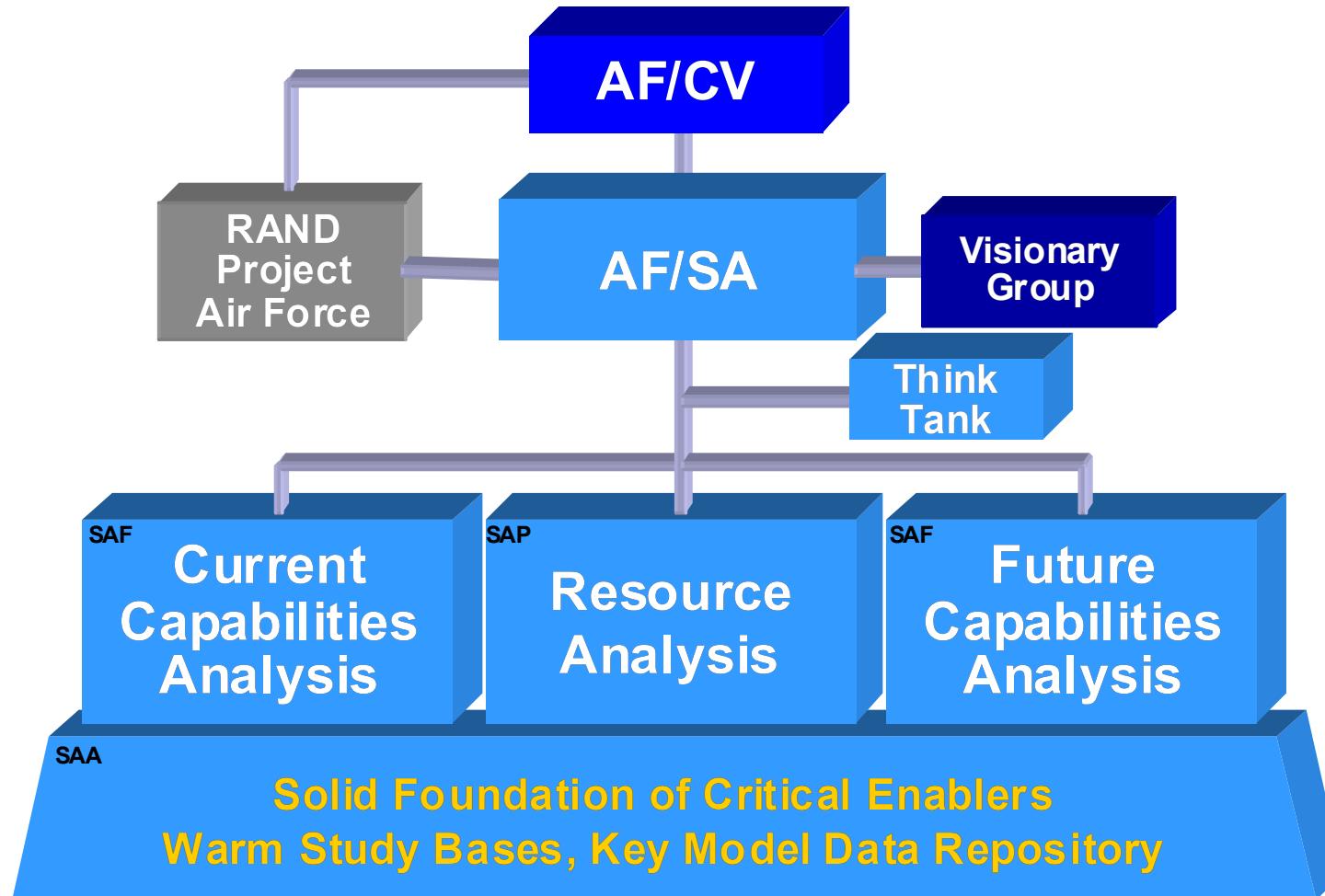
**L3**  
communications  
Analytics Corporation

**STI**  
Simulation Technologies, Inc.



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# AFSAA/SAA - Analyses Foundations Directorate





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# **SAA - Focus Areas**

## **AFSAA Organization**

- SAC
- SAF
- SAP
- SAA



### **■ Analyst Development**

- Total Force Career Field Review; Scientist & Engineer Career Panel
- Career field management, AAD
- Training, AFORS, MORS

### **■ Analyst Tools**

- AF analytic M&S requirements
- JWARS, STORM

### **■ Analytic Warmbase**

- Baseline Data and Scenarios
- Study Support; Knowledge Management System

### **■ Analytic Community**

- AFAC Steering Group, AoA Users Group
- Analytic Centers of Excellence integration & collaboration



# ***Headquarters U.S. Air Force***

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*Integrity - Service - Excellence*

## **Model Manager**



Maj Bryn Turner

AFSAA/SAAP

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# Developer



## STORM Overview

*Designer's Perspective*

*Garth Morgan*

*16 May 2002*

The STORM logo, where the word 'STORM' is written in a bold, black, sans-serif font. A blue swoosh graphic starts from the left and curves around the letter 'T', ending under the letter 'R'.



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# *Background*

## *Program History*

- Began work in October 1996 as analytical analogue to training simulation
  - National Air and Space Model (NASM)
- Subsequently envisioned as parallel development to inform DoD campaign-level tool
  - Joint Warfare System (JWARS)
- Eventually established as the Air Force's next-generation campaign-level analysis tool
  - Synthetic Theater Operations Research Model (STORM)





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# User Requirements

## Program Goals

- A successor for THUNDER
- Improving campaign analysis is STORM's primary objective
  - Building a better model is only a part (albeit an important part) of that
- User Space Analysis revealed the major desired improvements
  - Realize a comprehensive yet graduated core model domain representation (air / space / land / sea)
    - Provide a better "Joint" feel without compromising aerospace focus
  - Provide an integrated warfighting representation
    - Integrate C<sup>2</sup>, ISR, Communications and Logistics with traditional combat functionality
  - Enhance analytical utility
    - Promote transparency throughout input / operation / output
    - Balance breadth and depth across functionality
  - Improve operation and maintenance
    - Anticipate and accommodate change over the M&S life-cycle



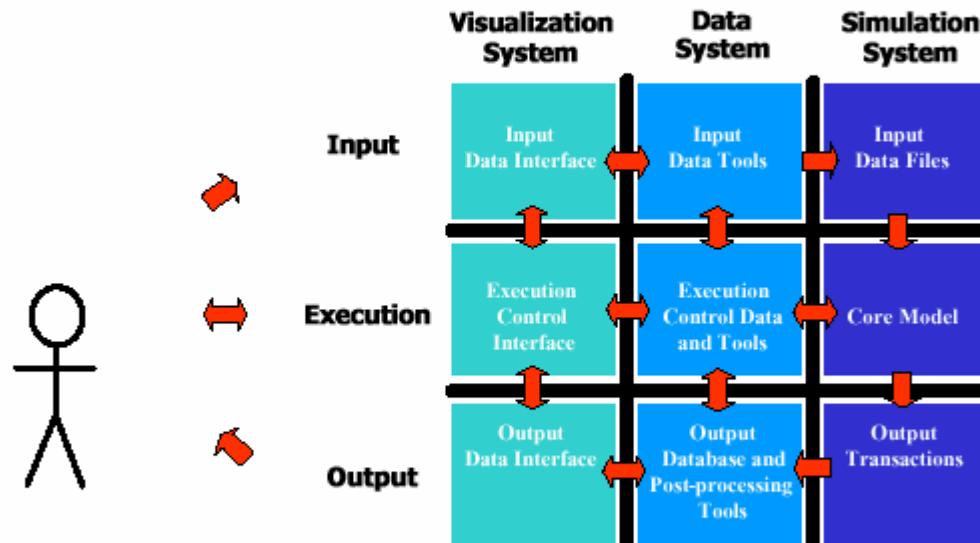


# Common Analytical System Architecture (CASA)

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## STORM System Architecture

- Functional partition and information / control flows

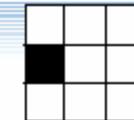




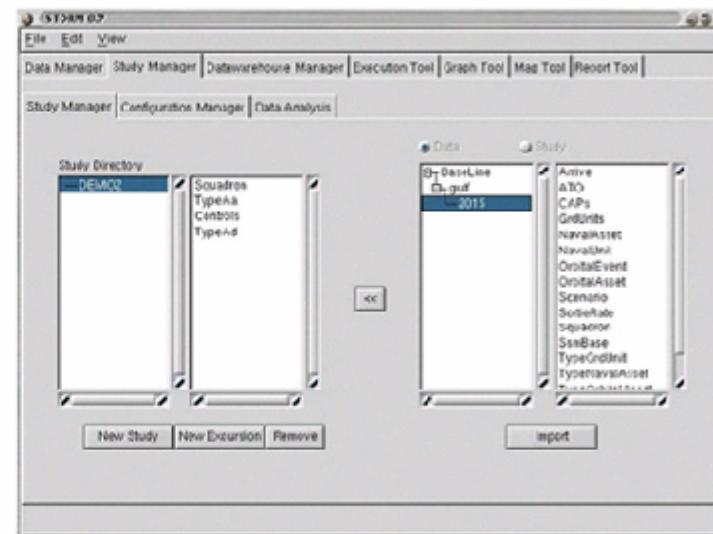
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# Studytool GUI for Execution

## Execution Control Interface



- Intent
  - Supplement functional but “unsexy” command line interface built from UNIX scripts with “user-friendly” GUI
- Implementation
  - Study Tool is a GUI built over top of scripts
  - Enables user to
    - Select input data files
    - Execute model (“ttrun”)
    - Specify reps
  - Provides single-point interface to Input and Output Visualization tools

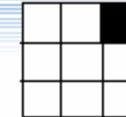




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# Editable Flat File Input

## Input Data Files



- Intent
  - Use human-readable flat files
    - Decouples the model from supporting input tools
    - Provides standardized data interchange format between core model and any input data import / manipulation tool
    - Makes it easy for users to build custom tools
      - Recent example: French “*THUNDER Embout Avant*” (“THUNDER Front End”) to facilitate air mission planning
- Implementation
  - Similar to THUNDER in scope and number (100 +)

| 123 software             |                   |                  |                        |                        |
|--------------------------|-------------------|------------------|------------------------|------------------------|
| Window                   | Edit              | Options          |                        | Help                   |
| /home/norman/STORMdata\$ |                   |                  |                        |                        |
| ada.dat                  | arc.dat           | ground2.dat      | nearareplan.dat        | typesd.dat             |
| aga.dat                  | arrive.dat        | finplan.dat      | region.dat             | typesdiwert.dat        |
| asplanner.dat            | atcboard.dat      | 1005.dat         | s2a.dat                | typesimunit.dat        |
| asppriority.dat          | ato.dat           | 1splan.dat       | scenario.dat           | typessetactical.dat    |
| asppufile.set            | battle.space.dat  | logbook.dat      | seadplan.dat           | typesaturation.set.dat |
| edstyt.dat               | cap.dat           | logsystem.dat    | separationfunction.dat | typesresset.dat        |
| ewm.intenace.dat         | couplet.dat       | measurement.dat  | side.dat               | typesrunit.dat         |
| odmode.dat               | chokect.dat       | mengsdata.dat    | sonicrate.dat          | typesvalset.dat        |
| odset.dat                | couplet.dat       | node.dat         | spacetime.dat          | typesvalset.dat        |
| opline.dat               | control.dat       | neuraldamage.dat | soilrate.dat           | typesvalset.dat        |
| optrainert.dat           | decoman.dat       | novalunit.dat    | soilshape.dat          | typesvalset.dat        |
| airbase.dat              | distri-button.dat | node.dat         | surfavatarget.dat      | typesvalset.dat        |
| aircommand.cat           | wnc1.dat          | oblivient.dat    | tancerepair.dat        | typesvalset.dat        |
| airdetectsens1.dat       | global.table.dat  | orbitalasset.dat | terrain.dat            | typesvalset.dat        |
| airrops.dat              | ericonmand.dat    | paths.cat        | transactions.dat       | water.dat              |
| airunitclasses.dat       | erudum.t.dat      | rundomseedes.cat | traspade.dat           |                        |
|                          |                   |                  | typeba.dat             |                        |
|                          |                   |                  |                        |                        |
|                          |                   |                  |                        |                        |



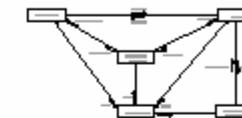
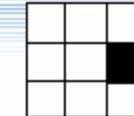


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# ***Functional Model***

## **STORM Conceptual Model**

- Logical partition of core model functionalities
  - An analyst's view
  - Horizontal "slices" across the metamodel
- Structure of the remainder of this overview briefing
  - Air
  - Space
  - Ground
  - Naval
  - ISR
  - Mobility
  - Logistics





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# Air Mission Functionality

## Air Missions

| STORM        | STORM   | THUNDER         | Description          | Target/<br>Assignment |
|--------------|---------|-----------------|----------------------|-----------------------|
| Meta-mission | Mission | Equivalent(s)   |                      |                       |
| CAS          | PCAS    | CAS             | Close Air Support    | Grd Unit (close)      |
| AI           | PAI     | INT, BAI        | Non-CAS Strike       | Grd Unit              |
|              |         | ~INT            |                      | Comm Node             |
|              |         | INT             |                      | Logistics Node        |
|              |         | INT             |                      | Transhipment Node     |
|              |         | INT             |                      | Choke Point           |
|              |         | INT             |                      | Supply Unit           |
|              |         | INT             |                      | Air Defense Node      |
| OCA          |         | OCA             |                      | Airbase               |
|              |         | ~INT            |                      | C2 Node               |
|              |         | STI             |                      | Surface Target        |
|              |         | ~OCA            |                      | Naval Unit            |
|              |         | ~OTBM           |                      | SSM Base              |
|              | XAI     | ~OTBM           | Air Alert AI         | Orbit Pt              |
| OCA          | SWEP    | none            | Fighter Sweep        | SWEP Location(s)      |
|              | GOCA    | HVAAC           | Ground Alert OCA     | Ground Alert          |
|              |         | ODCA            |                      |                       |
|              | OESC    | AIRESC          | Fighter Escort       | Pen. Friendly Pkg     |
|              | OCAP    | FSWP            | Offensive BARCAP     | Orbit Pt              |
| DCA          | DCAP    | BARCAP          | Defensive BARCAP     | Orbit Pt              |
|              | GDCA    | DCA             | Ground Alert DCA     | Ground Alert          |
|              | DESC    | none            | HVA Protection       | Friendly Orbiter      |
| SEAD         | DSUP    | DSEAD           | Direct Suppression   | AD Corridor           |
|              | ESUP    | ESUP            | Escort Suppression   | Pen. Friendly Pkg     |
|              | SSUP    | SSUP, CSUP      | Standoff Suppression | Orbit Pt              |
|              | EJAM    | EJAM            | Escort Jamming       | Pen. Friendly Pkg     |
|              | SJAM    | SJAM, CJAM      | Standoff Jamming     | Orbit Pt              |
| REC          | REC     | RECCE           | Reconnaissance       | Surface Asset         |
| AR           | AR      | AAR             | Air Refuelling       | Orbit Pt              |
|              |         | GAR             | Ground Alert AR      | Ground Alert          |
| HVA          | HVA     | AEW, SREC, DTBM | High Value Asset     | Orbit Pt              |
|              | GHVA    | AEW, SREC, DTBM | Ground Alert HVA     | Ground Alert          |

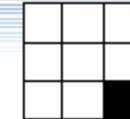
STORM  
17



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# **ASCII Flat File Output**

## **Output Transactions**



- Intent
  - User Space Analysis emphasized enabling users to drill deeper into known areas and explore unanticipated measures
- Implementation
  - All results contained in single ASCII flat file (“db.out”)
    - Self-defining database schema
      - Database structure explicitly included in file containing data to enable consistency checking
    - Third-normal form (no repeated information)
      - Minimizes file size
      - Reduces chance of errors and inconsistencies
      - Improves data access performance
    - Contains all key model interactions at “primitive” (vice aggregated) level
      - Supports both individual and rolled-up views
  - Debugging transactions and warning messages contained in other flat files

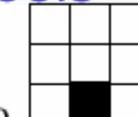
**STORM<sup>14</sup>**



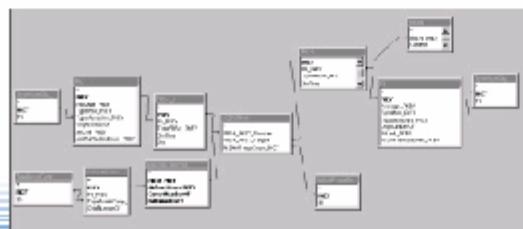
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# Additional Post-Processing

## Output Database and Post-Processing Tools



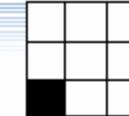
- Intent
  - User Space Analysis emphasized enabling users to drill deeper into known areas and explore unanticipated measures
- Implementation
  - Relational DBMS as the single point repository of all model results
    - Currently support Oracle and MySQL
  - Transactional database form for map support and detailed drilldown
  - Data warehouse form for graphing / reporting rolled-up view
  - Support utilities to load the transactional databases and the data warehouse from the transactions
  - SQL Mapping Description Language (SMDL)
    - Enhanced, database-independent query language



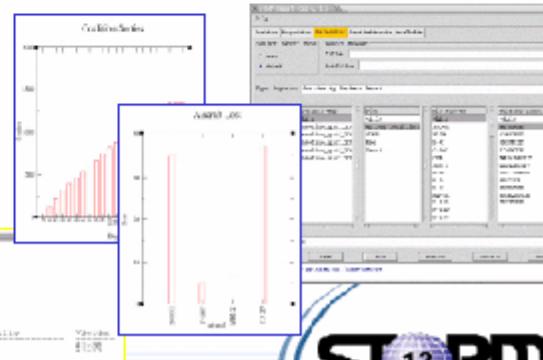
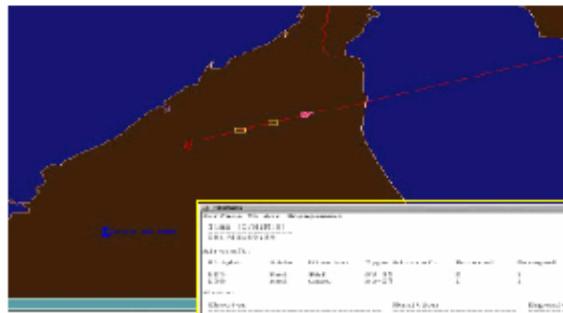


# *Output Tools*

# Output Data Interface



- Intent
    - User Space Analysis emphasized transparency of results, depth of insights and ease of use
  - Implementation
    - Currently has
      - MapTool with both OILSTOCK and Arcview GISs
      - GraphTool with GRACE, Gnuplot and Excel plotting packages
      - ReportTool with XML technology to support HTML browser display and comma-separated format (.csv)

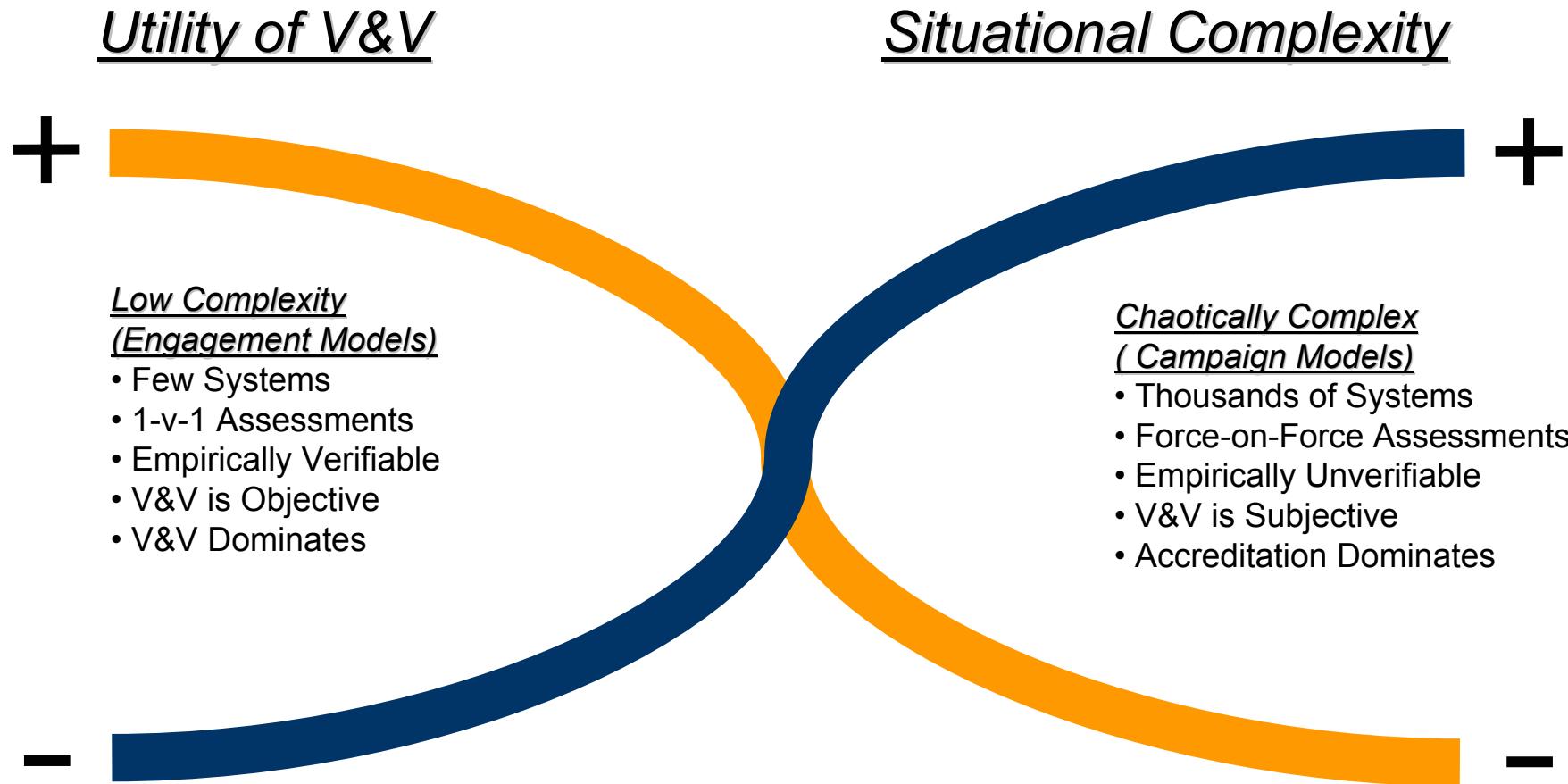


**STORM<sup>12</sup>**



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# The Spectrum of V&V

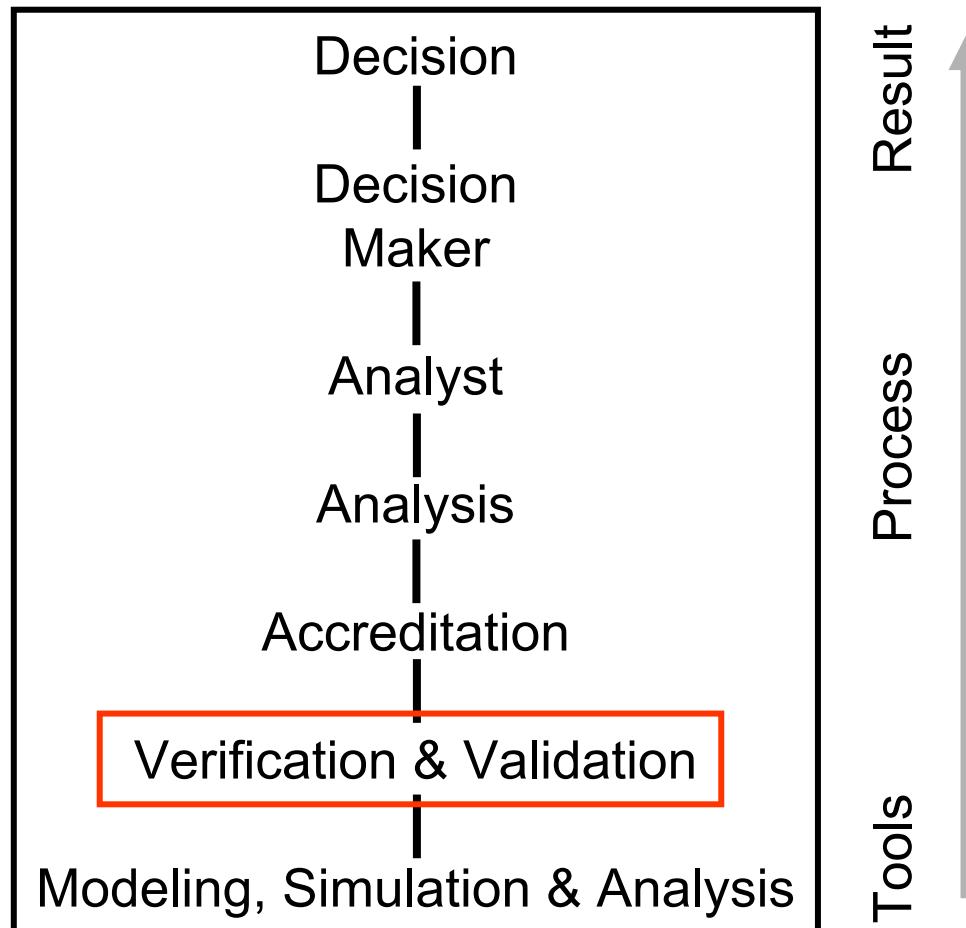


Source: LtCols Smither and Langbehn: "Taking a Functional Approach to M&S Policy" in Mar 02 PHALANX



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# Decision Making Perspective: Theory and Practice



Source: LtCols Smither and Langbehn: "Taking a Functional Approach to M&S Policy" in Mar 02 PHALANX



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# *Governing Documents*

- DoD Directive 5000.59, DoD Modeling and Simulation Management, 1 Apr 94 w CH1, 20 Jan 98
- DoD Instruction (DoDI) 5000.61, DoD Modeling and Simulation Verification, Validation, Accreditation (VVA), 29 Apr 96
- DoD Recommended Practices Guide (RPG), VV&A Printable Documents at <http://www.msiac.dmso.mil/vva/default.htm>
- AFPD 16-10, Modeling and Simulation Management, 30 Jan 95
- AFI 16-1001, Verification, Validation, Accreditation (VVA), 1 Jun 96



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# DoDD 5000.59

## Basic Definitions

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- **Verification**--The process of determining that a model implementation accurately represents the developer's conceptual description and specifications.
- **Validation**--The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model.
- **Accreditation** -- The official determination by the accreditation authority that the M&S is acceptable for a specific purpose



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# **AFI 16-1001**

## **V&V Concepts**

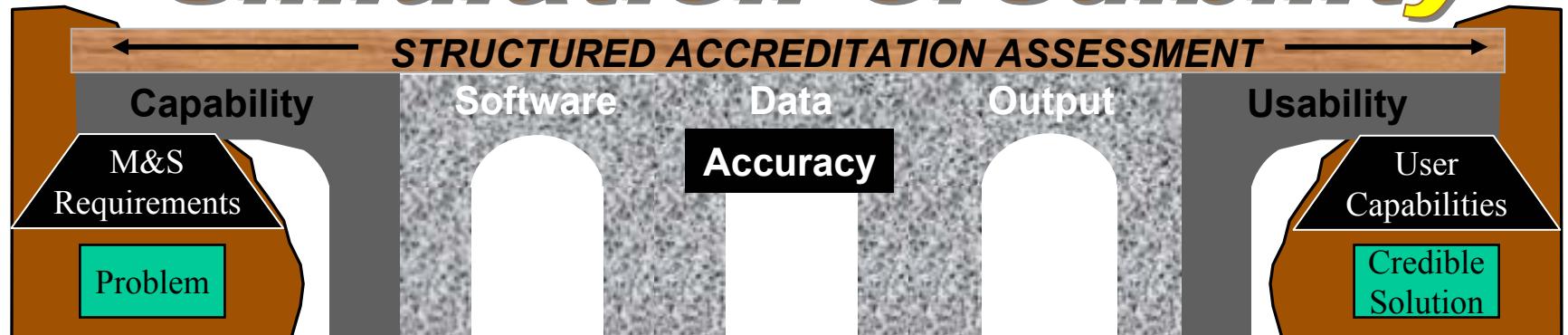
- V&V is a continuous process throughout a model's lifecycle
- Different V&V activities are sponsored to support specific accreditation needs
- A systematic V&V plan will be part of M&S development
- V&V activities support model acceptance/accreditation requirements defined by the accreditation authority
- Models must meet V&V requirements of managing MAJCOM, FOA or DRU
- V&V agent performs all V&V activities and prepares a final V&V report



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# Putting It All Together

## Simulation Credibility



### CAPABILITY

Simulation possesses all required functionality and fidelity for the problem being solved

### USABILITY

Simulation has adequate user support to facilitate correct operation and interpretation of its outputs

**Process of Accreditation Assesses All These Factors!**

Source: <http://www.xo.hq.af.mil/xoc/8-ToolKit-VVandA-DAMM5> (JASA Brief to DAMM SG 11/00)



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## ***Major STORM Milestones***

- Program Initiation - Late 1996
- Version 0.7 Delivery - May 2001
- User Group Meeting - May 2002
- Version 1.0 Delivery - Dec 2002
- User Group Meeting - May 2003
- AFSAT Entry - Feb 2004
- Retire Thunder at AFSAA - May 2004
- User Group Meeting - May 2004
- Version 1.1 Delivery - TBD

Source: STORM CRLCMP, 3 Jan 2002



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# Criteria for AFSAT Entry



## Mandatory Toolkit Criteria

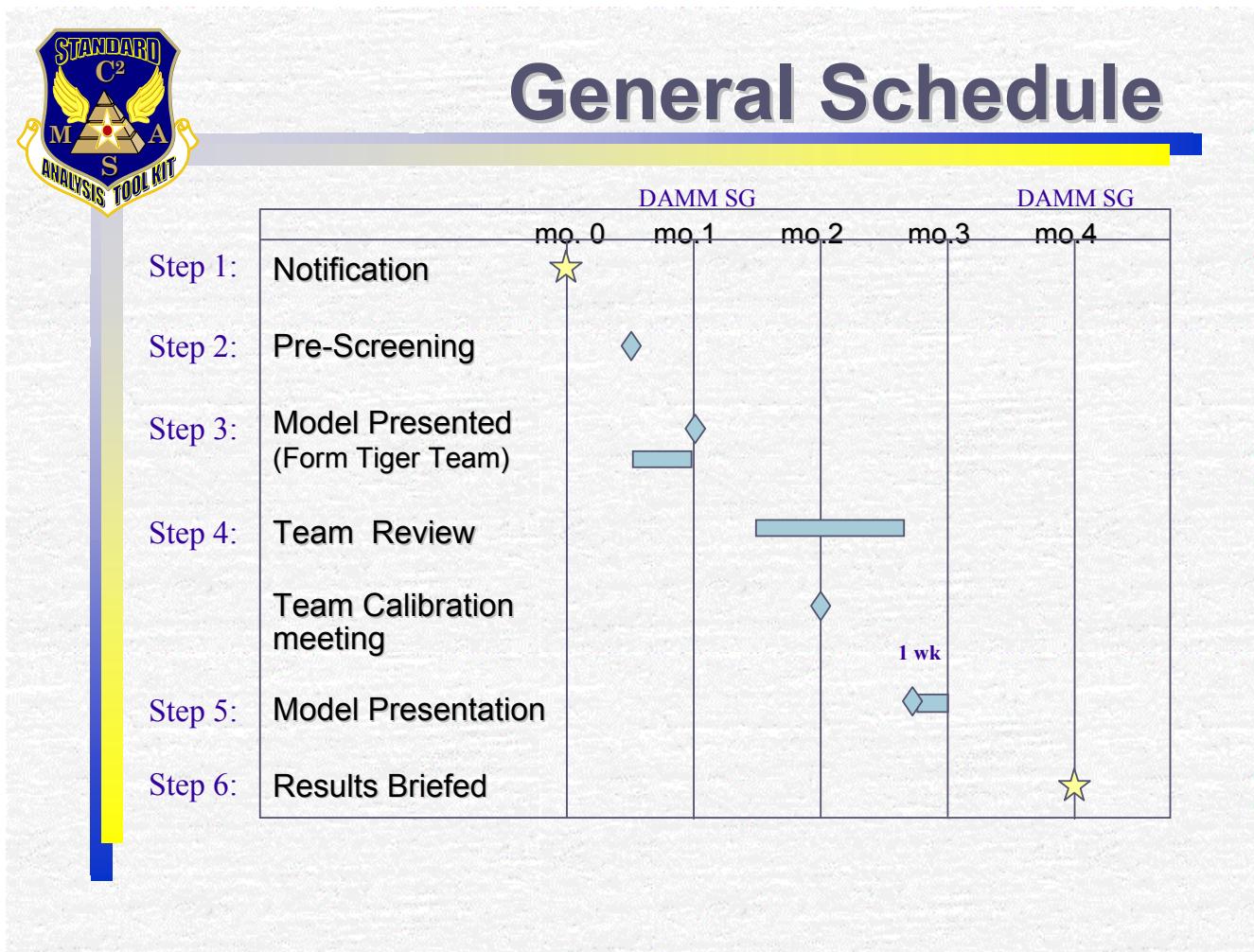
- The model provides data/answers/insights that addresses a critical AF analytic capability
- Documentation is complete and comprehensive
- There is a configuration management process
- There is support to the using community and infrastructure
- There is a base of already accomplished model V&V documented and available

Detailed criteria descriptions used  
for Tiger Team evaluations



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# AFSAT Entry Process



Source: [http://www.xo.hq.af.mil/cgi-bin/dir\\_list.pl/XOCA/DAMMSG/AFSAT](http://www.xo.hq.af.mil/cgi-bin/dir_list.pl/XOCA/DAMMSG/AFSAT)



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# VV&A of New Models

**VV&A Recommended Practices Guide**

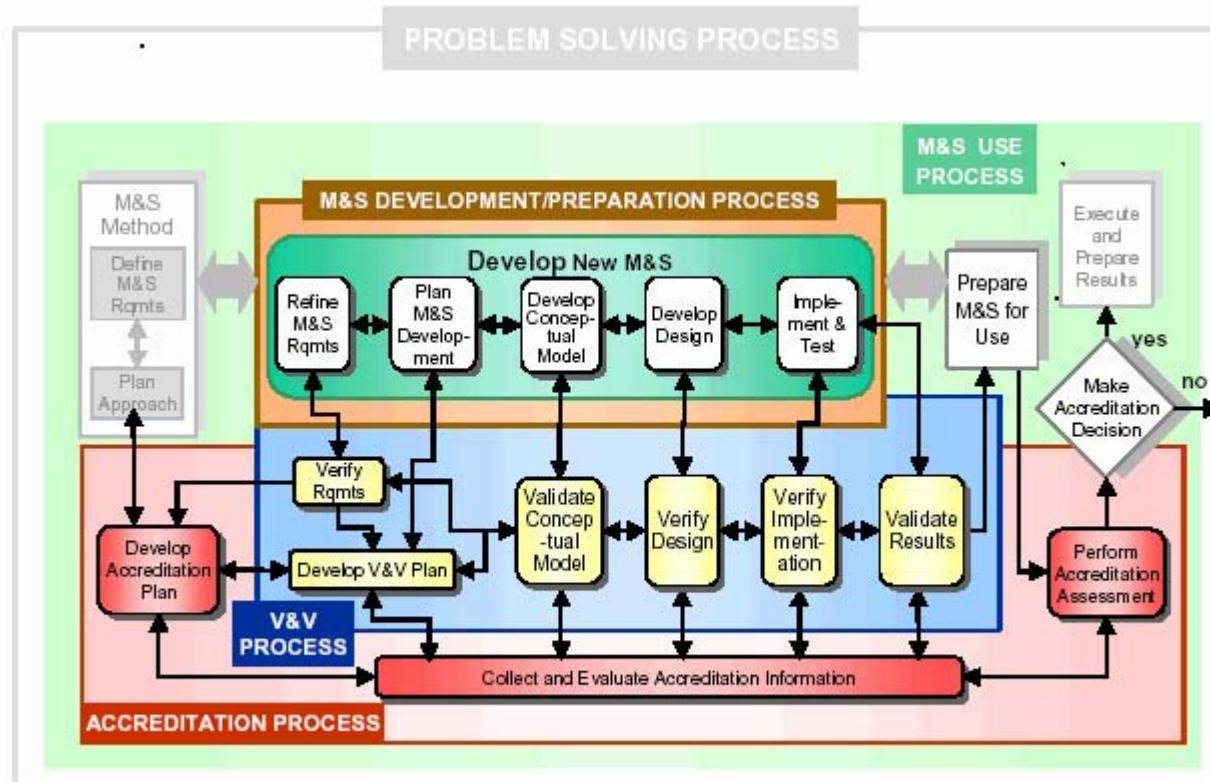
**Table of Contents**

|  |    |
|--|----|
| <b>VV&amp;A Responsibilities and Challenges</b>                                | 1  |
| How Does the V&V Agent Impact a New M&S Development Effort?                    | 1  |
| How Does a New Development Effort Impact the Way the V&V Agent Operates?       | 2  |
| What Are the V&V Agent's Responsibilities in Simulation Development?           | 3  |
| What Challenges Does the V&V Agent Face Relative to VV&A?                      | 4  |
| <b>Role of the V&amp;V Agent in the Overall Problem Solving Process</b>        | 9  |
| Problem Solving Process  | 9  |
| M&S Use Process  | 10 |
| M&S Development/Preparation Process  | 11 |
| <b>VV&amp;A Functions of the V&amp;V Agent Role in New M&amp;S Development</b> | 12 |
| Differences Between Verification and Validation                                | 12 |
| Verify Requirements  | 13 |
| Develop V&V Plan   | 17 |
| Validate Conceptual Model  | 22 |
| Verify Design  | 27 |
| Verify Implementation  | 30 |
| Validate Results   | 32 |
| Other Considerations   | 37 |
| <b>V&amp;V Agent's Relationship with Other Roles</b>                           | 39 |
| VV&V Agent's Relationship with the User  | 40 |



# V&V Process for New M&S Development

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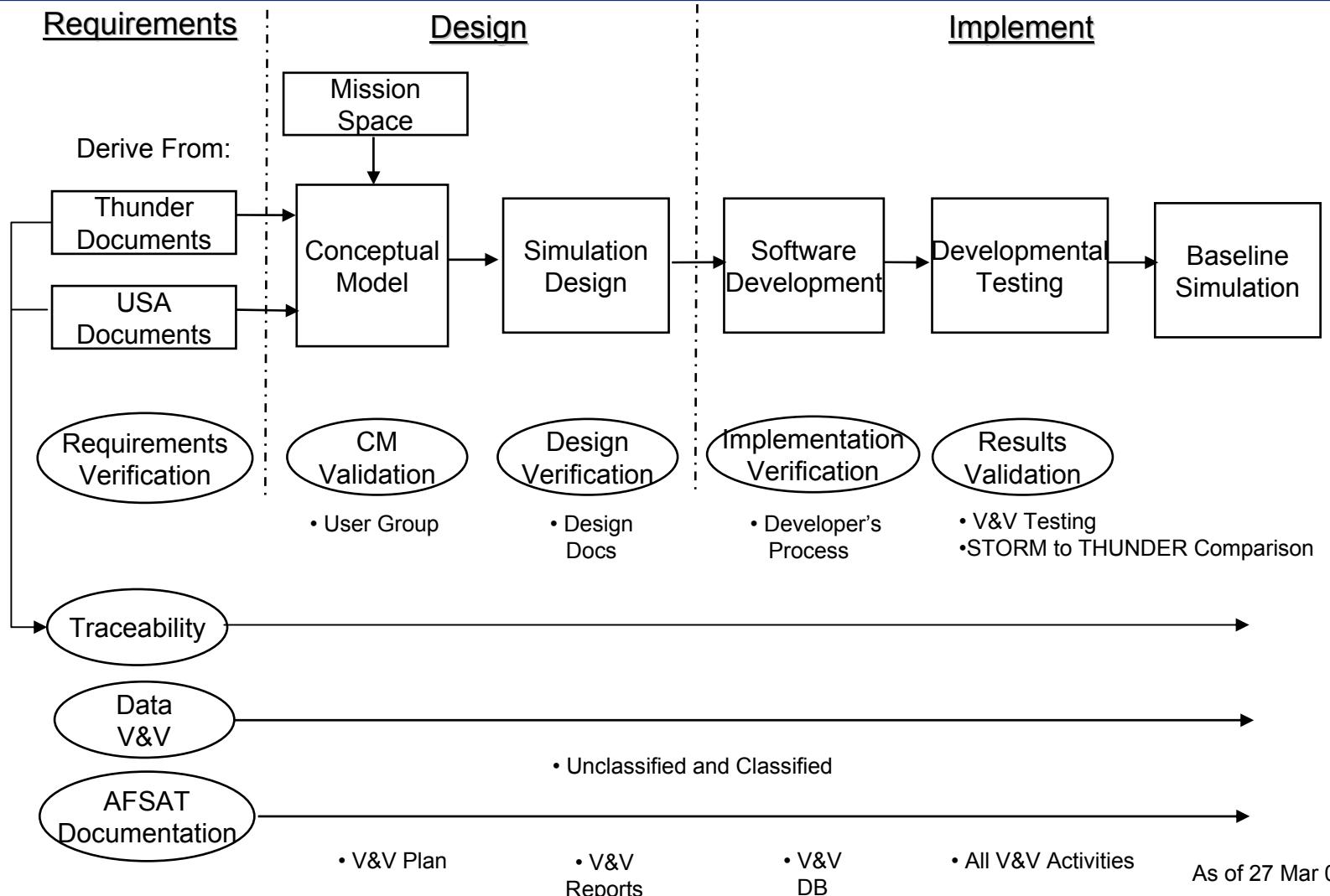
M&S Development/Preparation Process for New M&S

Source: The V&V Agent's Role in the VV&A of New Simulations, DoD VV&A RPG, 5/15/01



# STORM V&V Process

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# *Conceptual Model Mapping*

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# *Design Verification Mapping*

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Ready



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# Design Verification Mapping

| Problem Domain           | Aerospace Missions  | Derived Requirements | Conceptual Model Matrix | N/A and Pending from Conceptual Model Matrix | Related Documents: Development Interim Reports (DIR) and Interim Development Reports (IDR) |        |        |        |        |        |        |        |
|--------------------------|---------------------|----------------------|-------------------------|--|--|--------|--------|--------|--------|--------|--------|--------|
|                          |                     |                      |                         |  | ZPRD 1   | ZPRD 2 | ZPRD 3 | ZPRD 4 | ZPRD 5 | ZPRD 6 | ZPRD 7 | ZPRD 8 |
| Counter Air              | OCA                 | Other AFDD1          |                         |  |  |        |        |        |        |        |        |        |
|                          | TBM/CM              | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
|                          | C2 Attack           | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
| Counter Space            | DCA                 | Other AFDD1          |                         |  |  |        |        |        |        |        |        |        |
|                          | TBM/CM              | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
| Counter Land             | AI                  | TBM/CM               | AFDD1                   |  |  |        |        |        |        |        |        |        |
|                          | C2 Attack           | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
|                          | Other               | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
| Strategic Attack         | CAS                 | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
| Counter Information      | OCI                 | SEAD                 | AFDD1                   |  |  |        |        |        |        |        |        |        |
|                          | EW                  | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
|                          | Other               | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
|                          | DCI                 | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
| Counter Sea              | Air-to-Surface      | AFDD1                |                         |  |  |        |        |        |        |        |        |        |
| Air-to-Air               | AFDD1               |                      |                         |  |  |        |        |        |        |        |        |        |
| Anti-Ship                | AFDD1               |                      |                         |  |  |        |        |        |        |        |        |        |
| Intelligence             | AFDD1               |                      |                         |  |  |        |        |        |        |        |        |        |
| Surveillance             | AFDD1               |                      |                         |  |  |        |        |        |        |        |        |        |
| Reconnaissance           | AFDD1               |                      |                         |  |  |        |        |        |        |        |        |        |
| Navigation & Positioning | AFDD1               |                      |                         |  |  |        |        |        |        |        |        |        |
| Ground Warfare           | Armer               | AUTL                 |                         |  |  |        |        |        |        |        |        |        |
|                          | Infantry            | AUTL                 |                         |  |  |        |        |        |        |        |        |        |
|                          | Artillery           | AUTL                 |                         |  |  |        |        |        |        |        |        |        |
|                          | Airborne            | AUTL                 |                         |  |  |        |        |        |        |        |        |        |
| Naval Warfare            | Aviation            | AUTL                 |                         |  |  |        |        |        |        |        |        |        |
|                          | Mine Counter Mine   | HTL                  |                         |  |  |        |        |        |        |        |        |        |
|                          | Surface Warfare     | HTL                  |                         |  |  |        |        |        |        |        |        |        |
|                          | Subsurface Warfare  | HTL                  |                         |  |  |        |        |        |        |        |        |        |
|                          | Amphibious Assault  | HTL                  |                         |  |  |        |        |        |        |        |        |        |
|                          | Carrier Operations  | HTL                  |                         |  |  |        |        |        |        |        |        |        |
| Unconventional Weapons   | Nuclear             | ALL                  |                         | N/A  |  |        |        |        |        |        |        |        |
|                          | Biological          | ALL                  |                         | Pending                                      |  |        |        |        |        |        |        |        |
|                          | Chemical            | ALL                  |                         | Pending                                      |  |        |        |        |        |        |        |        |
|                          | Radiochemical       | ALL                  |                         | Pending                                      |  |        |        |        |        |        |        |        |
| Strategic Effects        | Non-lethal          | ALL                  |                         | N/A  |  |        |        |        |        |        |        |        |
|                          | Power Grid          | N/A                  |                         | N/A  |  |        |        |        |        |        |        |        |
|                          | Command & Control   | N/A                  |                         | Pending                                      |  |        |        |        |        |        |        |        |
|                          | Leadership          | N/A                  |                         | Pending                                      |  |        |        |        |        |        |        |        |
|                          | National Will       | N/A                  |                         | N/A  |  |        |        |        |        |        |        |        |
|                          | Production/Industry | N/A                  |                         | N/A  |  |        |        |        |        |        |        |        |
|                          | Population          | N/A                  |                         | N/A  |  |        |        |        |        |        |        |        |
|                          | Terrain             | N/A                  |                         | N/A  |  |        |        |        |        |        |        |        |



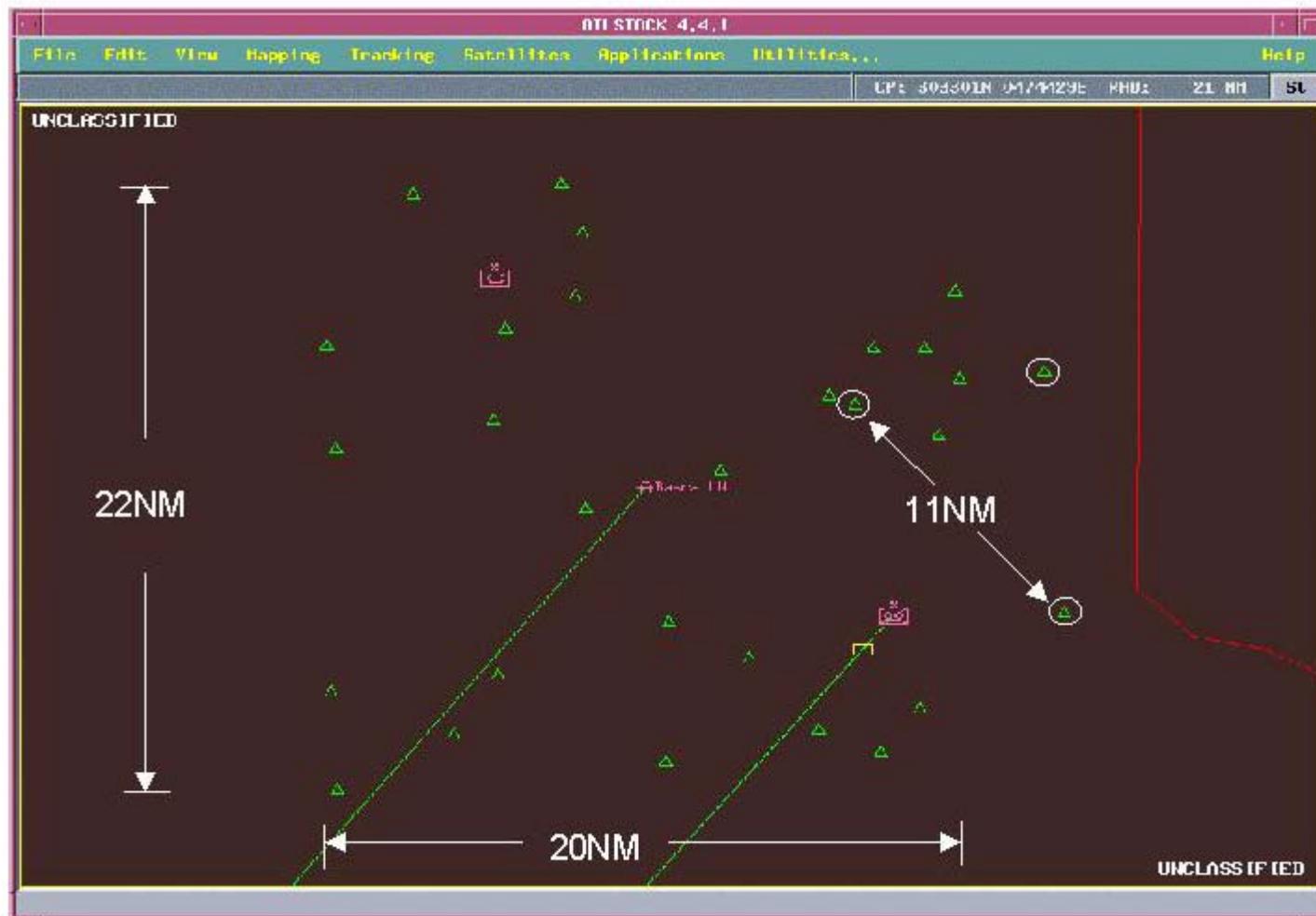
# *Implementation Mapping*

**U.S. AIR FORCE**



# Maptool Output from STORM v0.7

U.S. AIR FORCE



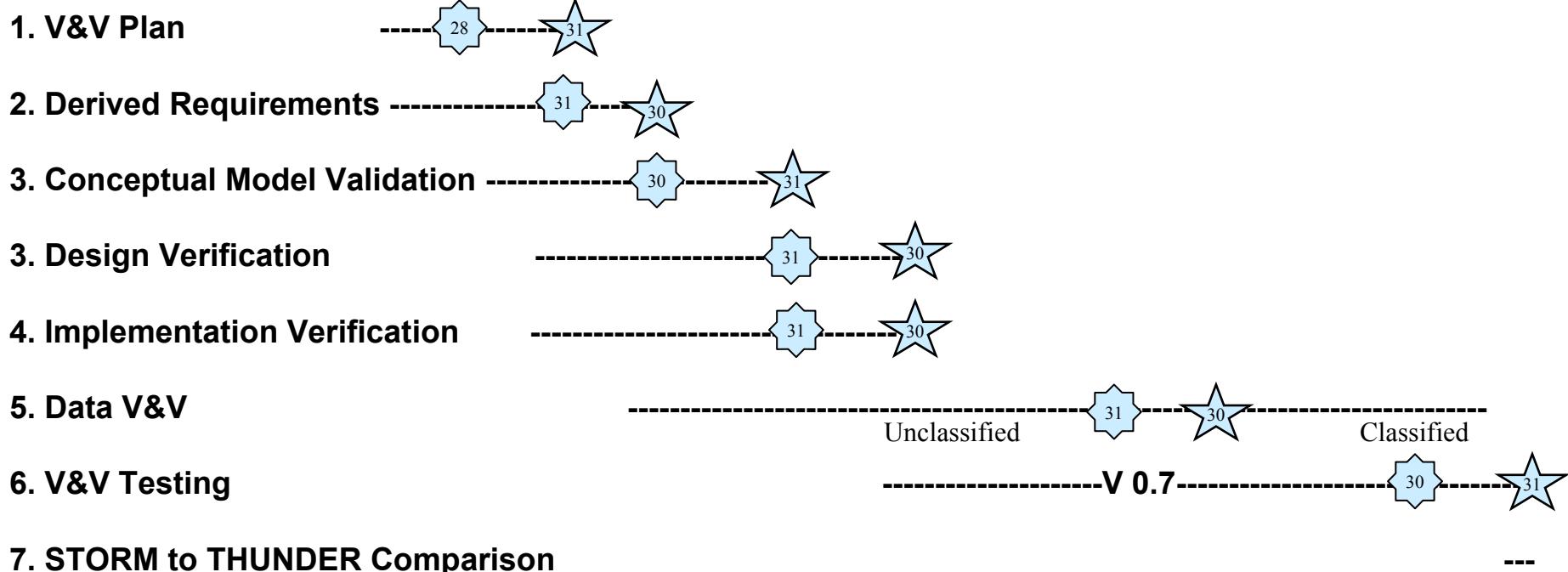


# Calendar Year 2002 Schedule

U.S. AIR FORCE

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

## Verification, Validation and Accreditation Activities



As of 27 Mar 02



# Calendar Year 2003 Schedule

U.S. AIR FORCE

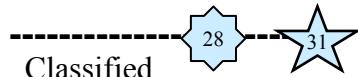
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Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

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## Verification, Validation and Accreditation Activities

5. Data V&V



7. STORM to THUNDER -----V 1.0-----



8. Evaluation Support Package / Final V&V Report



= Draft Document



= Final Document

As of 27 Mar 02



**U.S. AIR FORCE**

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# *Post AFSAT Entry V&V*

- V&V is a lifecycle M&S activity
- V&V for new STORM software releases
- Add-on scenarios and databases
- Study-specific accreditation