AI Methods for Corrosion

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GCAS®

GCAS Incorporated

- Founded in 1981, Incorporated in 2000
- Small Business located in San Marcos California
  - $1.2M Annual Revenue;
  - 10-people
  - Women-Owned SB Designation => Currently "in-Suspense"
- DUNS: 118594928
- CAGE: 6W067
- Facility Security Clearance
- NAICS Codes:
  - Primary: 541511 CUSTOM COMPUTER PROGRAMMING SERVICES
    - 511210   SOFTWARE PUBLISHERS
    - 541330   ENGINEERING SERVICES
    - 541512   COMPUTER SYSTEMS DESIGN SERVICES
    - 541513   COMPUTER FACILITIES MANAGEMENT SERVICES
    - 541690   OTHER SCIENTIFIC AND TECHNICAL CONSULTING SERVICES
    - 541711   RESEARCH AND DEVELOPMENT IN BIOTECHNOLOGY
    - 541712   RESEARCH AND DEVELOPMENT IN THE PHYSICAL, ENGINEERING,
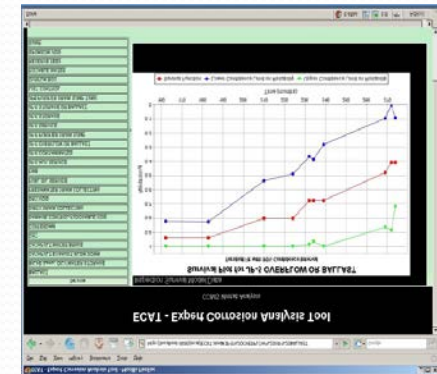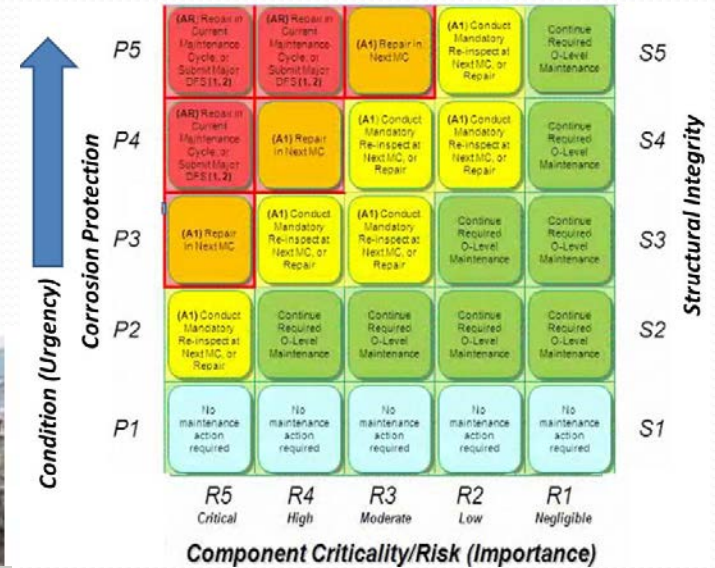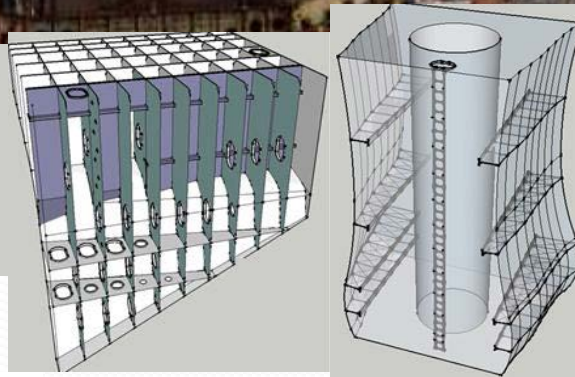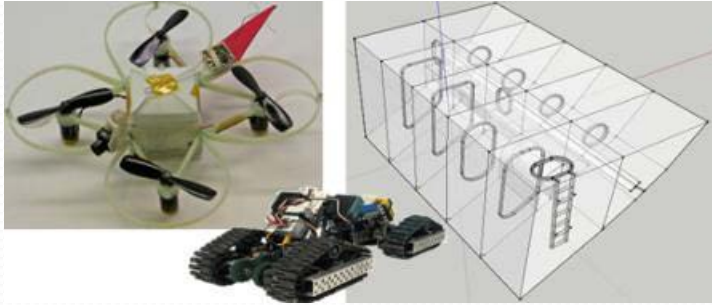- Prior Seaport Prime

Predictive Data Analytics

- Our Expertise:
  - Corrosion
  - Acoustics, Shock and Vibration
  - Planning and Scheduling
  - Expert Knowledge-Base Systems
  - Field Data Collection Systems
  - Diagnostic Systems (e.g., Medical Systems)
  - Advanced Probabilistic Methods
- Customers:
  - Army, Navy, AF, Darpa, MDA, DOT, NASA, NIH/NCI, PPG, LMCO, Scripps
- Previous Commercialization Ventures
  - GCAS Enterprise Accounting Suite (Job Costing, Project Management, e-Suite)
  - VC100 PC-based Vibration Control System
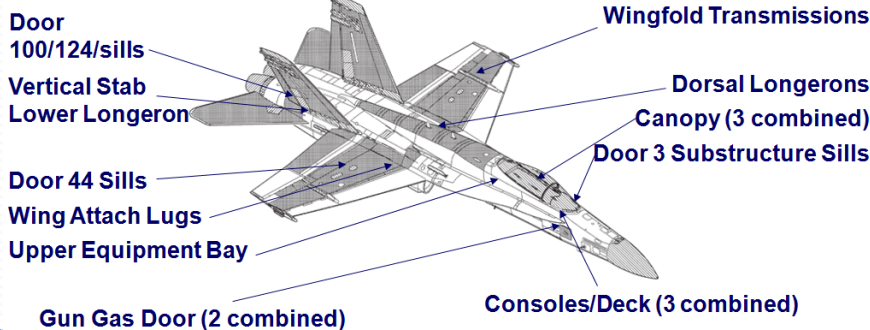 - ClipBoard Computer

Sample Contracts

- *Autonomous Tank and Void Inspection Flying Robots*
- *Tank and Void Inspection Software*
- *Expert Structure and Coating Analysis Tool (ECAT/ ESCAT)*
- *COORDBMS Corrosion Inspection Database System*
- *Aircraft Inspection and Repair System (AIRS)*
- *Data Mining and Analytics of NAVAIR Inspection Databases*
- *Corrosion Expert System (CES)*
- *Modeling of Coating System Deterioration from Field Data*
- *Accelerated Corrosion Expert Simulator for Automotive and Aircraft (ACES)*

Montage of T&V Corrosion

5

Montage of Aircraft Corrosion
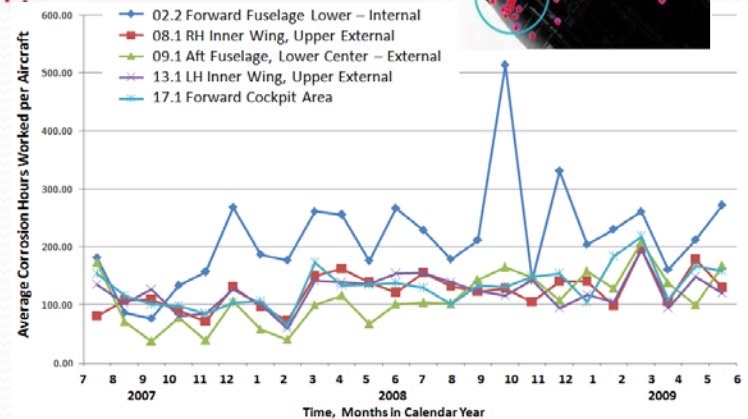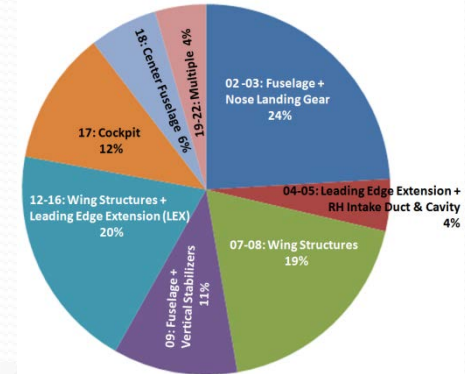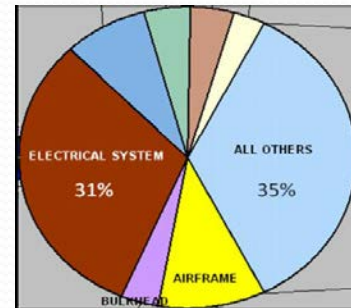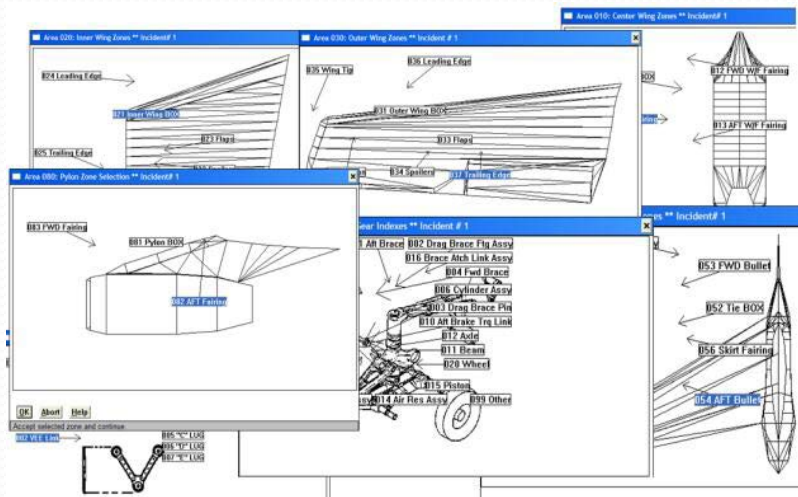
ACES Simulator
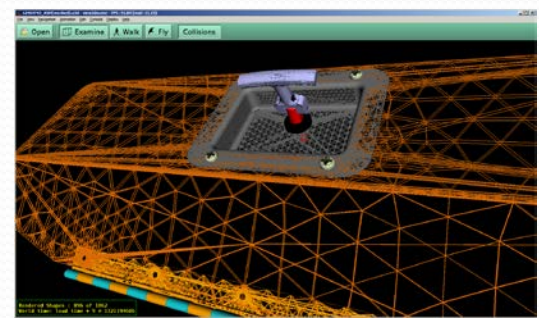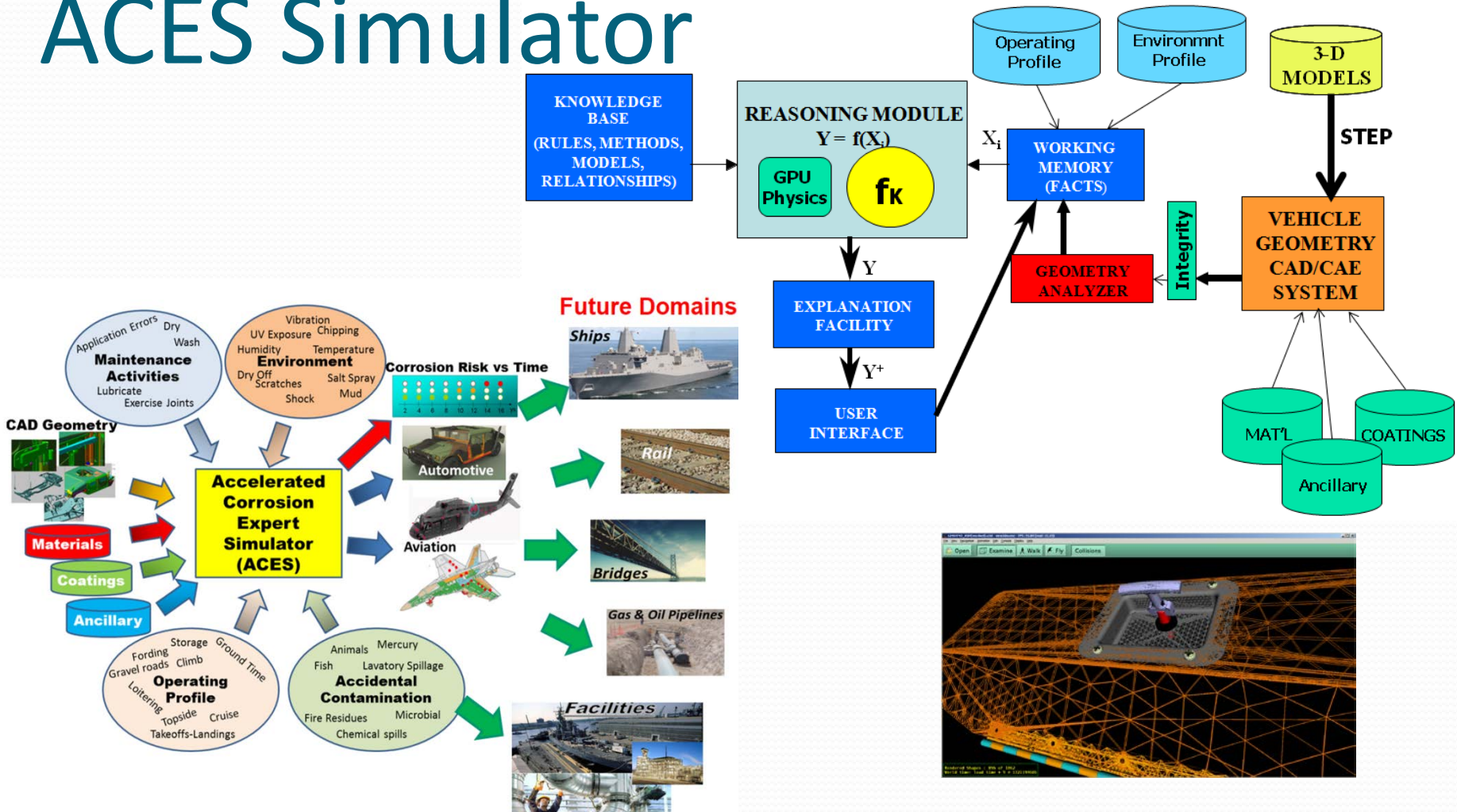
BACKUP SLIDES

ESCAT Process Flow

Inspection Software

Inspection

Repair

Data Storage And Cleanup

CCIMS

Parse Data

ECAT Analysis

Report File

Web Display

Data Analytics and Forecasting

GCAS.
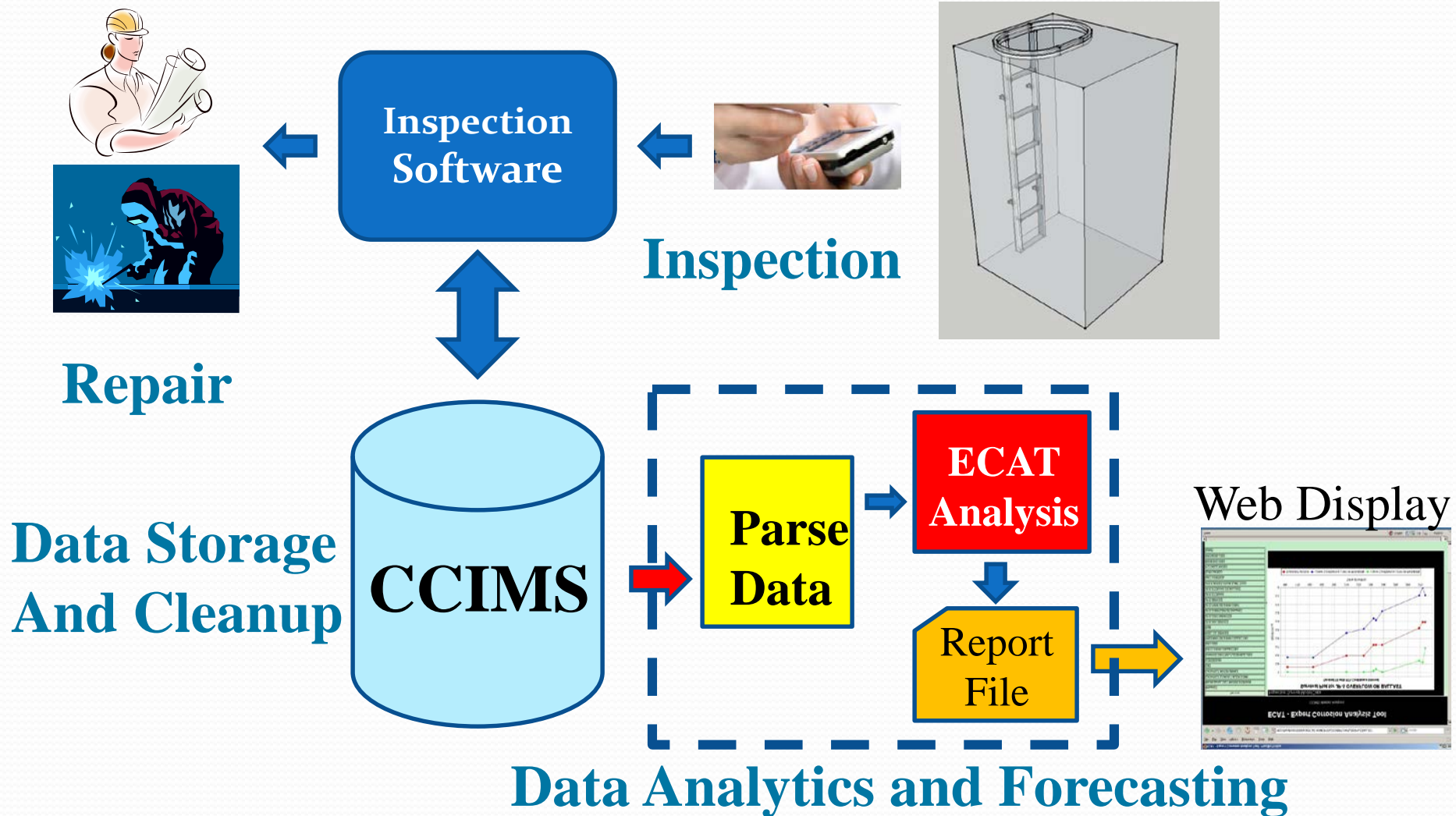
Corrosion Analysis is a Black Art

- Electro-Chemical ("Physics-based") procedural models have limited success.

- Turn to mystics, soothsayers, consultants for Heuristic Solutions

- And those who practice **AI**

What are AI Algorithms?

- **Originally:** *Methods that model the human thought process*
- Current expanded definition added Statistical and Optimization techniques used in Data Analysis, Data Mining and Decision Making
- "An algorithm that is not part of the current day convention or standard."

AI Analysis Approach

$$Y_j = f_k(x_i)$$

- Dimensions, X_i:
- Measures, Y_j:
- Methods, f_k:
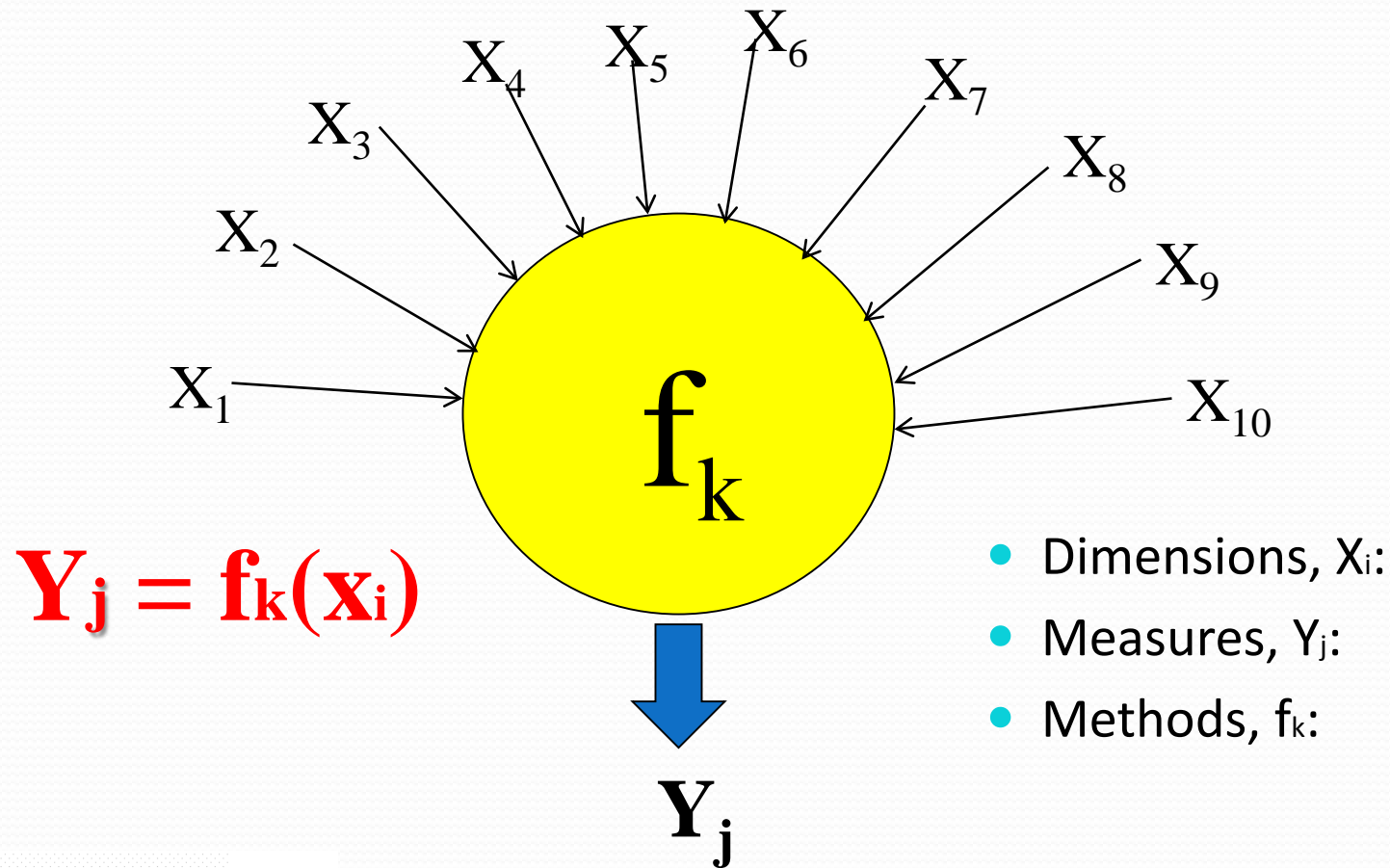
AI Methods

- ANOVA
- Weibull Analysis
- Monte Carlo
- Bayesian Networks
- Naïve Bayes
- Markov Model/Chains
- Neural Nets
- Genetic Algorithms

- Procedural (Physics-based: mechanical, electro-chemical, etc.)
- Decision Trees
- Rule-based Production Systems
- Linear/Logarithmic Regression
- Time Series

Rule-Based Expert System
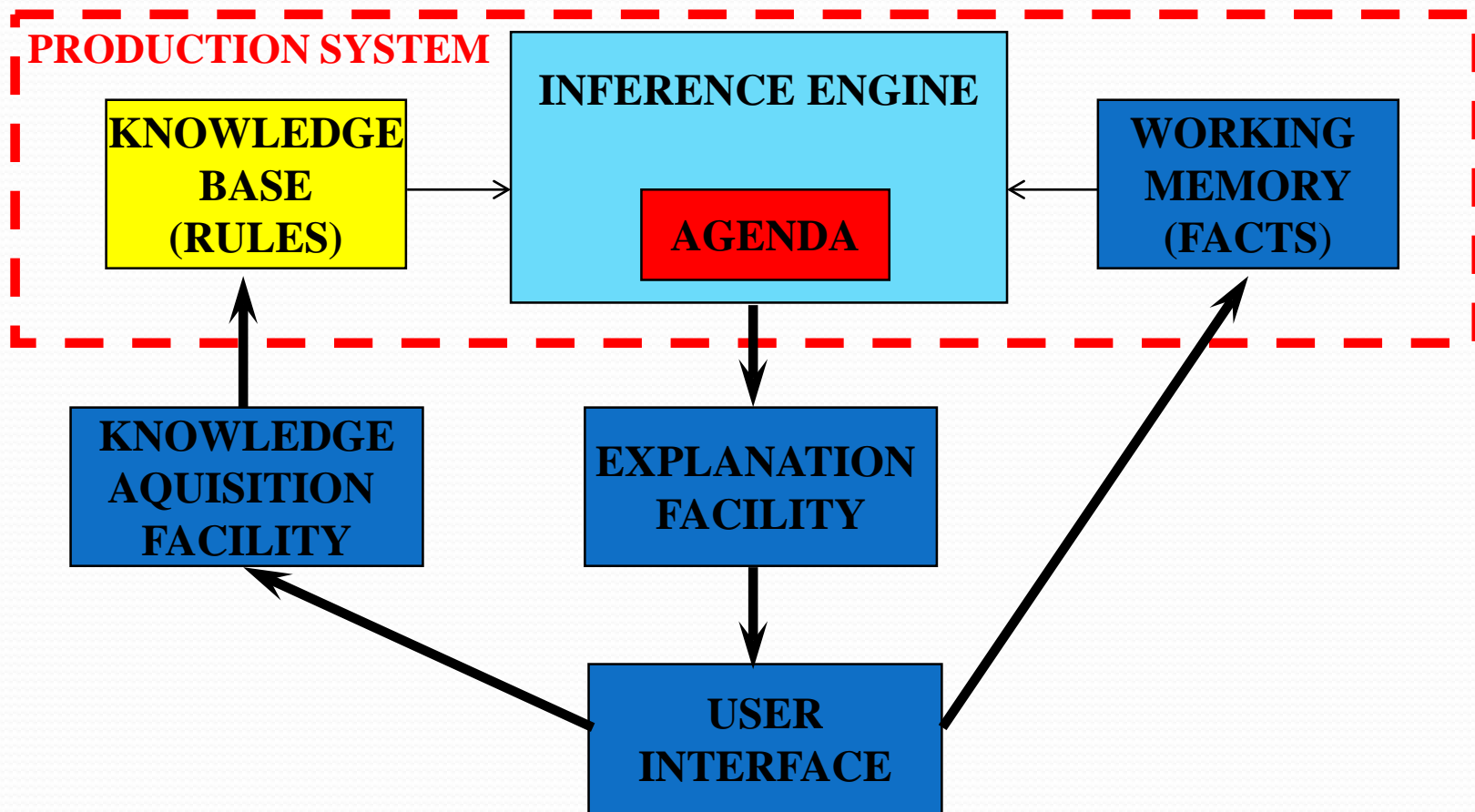
The Inference Engine

- Efficient Pattern Matching of Fact to Rules
- Conflict Resolution
- Execution of Rules
- Uncertainty Processing

Rules = Complex (Deep) Knowledge

**IF A is less than a
AND B lasts b
THEN H, h, may occur
with likelihood
between LL and LH**

Example rules from CES

- IF there is water AND there is an electrolyte THEN corrosive environment is present

- IF there is an electrolyte AND there is water THEN corrosive environment with likelihood=10 **Redundancy**

- IF there is a low resistivity electrolyte THEN there is a corrosive environment

- IF there is an insulator between metals THEN galvanic corrosion is possible

- IF there is an insulator between metals AND insulator doesn't last the life of the vehicle THEN galvanic corrosion is possible

Subsumption

Where does the KB come from?

- Procedural methods (Equations),
- Lessons-Learned,
- Test data,
- Observation, and
- Subject Matter Experts (SMEs)
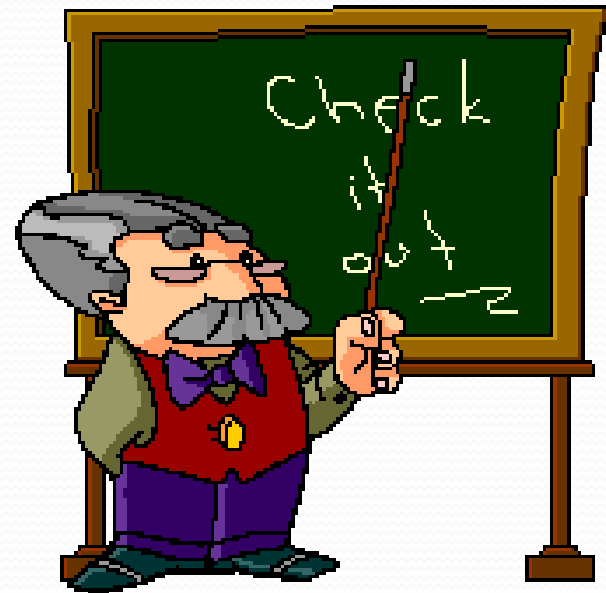
Reasoning under Uncertainty

- Uncertainty in the Rules
- Uncertainty in the Evidences

Quantifying Uncertainty

- Belief   [0.0 .. 1.0]   Bayesian Network

- Probability   [0.0 .. 1.0]   Markov Chains

- Confidence   [??? .. ???]   Dempster-Shaffer

- Likelihood   [-∞ .. +∞]

- Certainty Factors   [-5 .. +5]   Carnov

- Fuzzy Values   [low medium high]

Bayesian Network + CPT

Coating Selection Risk BN

Example of BN (CES)

Fording
True	50.0
False	50.0

Vehicle Area
Underbody	20.0
External BtB	20.0
External AtB	20.0
Underhood	20.0
In Cab	20.0

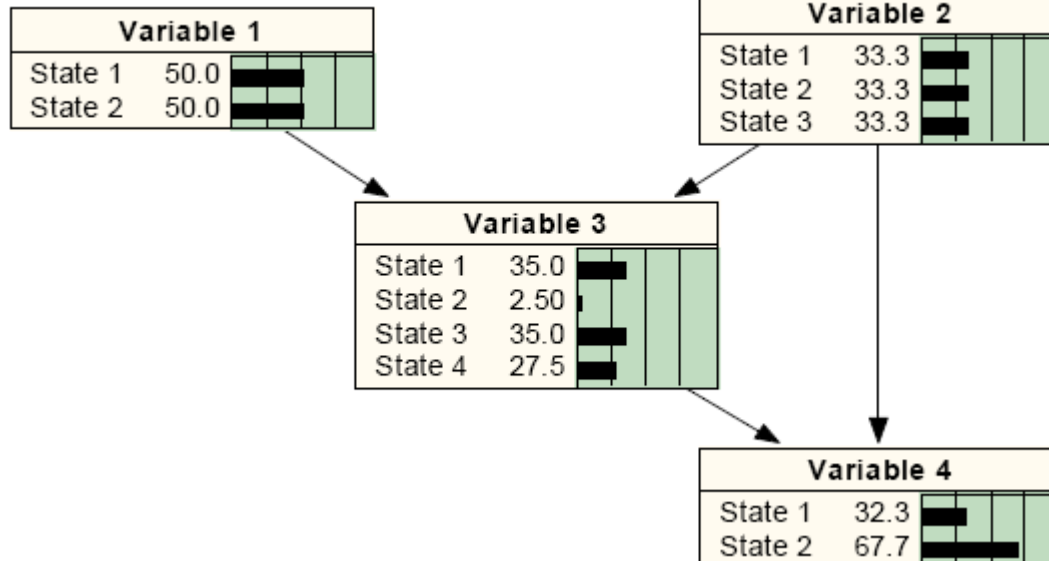**Electrolyte Isolation**
Effective	61.3
Marginal	34.5
Absent	4.17

Electrica...
Effective	6
Marginal	1
Absent	2

Corrosion Inhibitors
Present	50.0
Absent	50.0

Relative Motion
No	50.0
Yes	50.0

Isolation
Effective	85.5
Marginal	13.5
Absent	1.04

Temperature
Ambient	50.0
Elevated	50.0

Environmental Severity
Low	34.6
Medium	53.5
High	11.9

Mechanical Distresses
Low	40.6
High	59.4

Stress Level
Low	50.0
High	50.0

Poultice Entrapment
No	50.0
Yes	50.0

Crevices
Absent	50.0
Present	50.0

Impact
No	50.0
Yes	50.0

Drainage
Yes	50.0
No	50.0

Geometric Susceptibility
Low	62.5
High	37.5

Micro Environment Aggr...
Low	8.78
Medium	31.7
High	59.5

Assembly Susceptibility
Low	92.2
Medium	5.42
High	2.42

Galvanic Corrosion
Acceptable	48.6
Unacceptable	51.4

23

Turnbull/Weibull Analysis

SW AB 100% Failure = One Side with 3 Rating
LSXY Estimates-Arbitrary Censoring

Table of Statistics	
Shape	2.97257
Scale	14.0598
Mean	12.5500
StDev	4.59898
Median	12.4288
IQR	6.44682
AD*	42.125
Correlation	0.987

Markov Chain

Markov Transition Matrix

	New	Stage1	Stage2	Stage3	Stage4	Repair	Replace	R&M	TOTAL
Probability of Changing States MATRIX									
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New	1	.00	.00	.00	.00	.00	.00	.00	0
S-1	.00	.60	.25	.01	.00	.12	.00	.00	94
S-2	.00	.01	.85	.12	.00	.00	.00	.00	62
S-3	.00	.00	.00	.91	.00	.08	.00	.00	12
S-4	.00	.00	.00	.00	1	.00	.00	.00	0
Rpr	.00	.00	.00	.00	.00	1	.00	.00	0
Rpl	.00	.00	.00	.00	.00	.00	1	.00	0
R&M	.00	.00	.00	.00	.00	.00	.00	1	0