# SIERRA PROJECT

## Surveillance for Intelligent Emergency Response Robotic Aircraft

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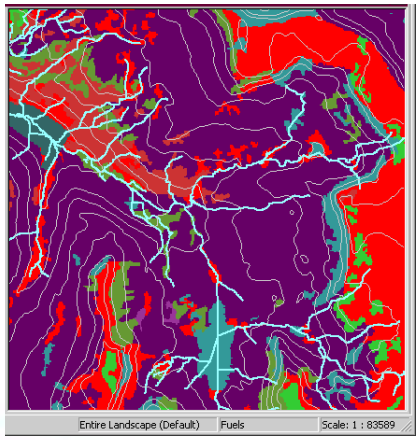
# What is SIERRA?

# What is SIERRA?

- Uses the Zephyr Unmanned Aerial System
- Supports wildland fire fighting team
- UAS system acquires live fire progression
- Uses GPS to incorporate location and terrain
- Data used to predict fire advancement

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# Problems facing SIERRA

- Unmanned Aerial Systems are too expensive!
- Prices of unmanned systems are driven up due to:
  - Huge number of certification tests
  - Certification process is lengthy and costly
- Ultimately, cost could be lower

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# Advanced Tactical UAS

- Globalhawk UAV system used by the USAF
  - Cost: Approx. $200 million
  - High range aircraft
  - High-tech surveillance capabilities


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# Tactical UAS

- AeroVironment RQ-11 Raven
  - Weight: 4.2 lbs
  - Endurance: 60-90 minutes
  - Speed: 28-60 mph
  - Range: 6.2 miles
  - Altitude: 15,000 ft.
  - Hand-launched vehicle
  - Cost: $250,000

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# SIERRA UAS

- Marcus UAV System
  - Weight: 5 lbs
  - Endurance: 60 minutes
  - Speed: 35-80 mph
  - Range: 9 miles
  - Altitude: 10,000 ft.
  - Hand-launched vehicle
  - Cost: $13,000

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# UAS Comparison

Zephyr

Cost: $13,000

RQ-11 Raven

Cost: $250,000

That's a difference of $237,000!! But why?

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# Purpose of Certification

- Airworthiness certification is necessary to:
  - Establish that the aircraft is capable of safe flight
  - Validate aircraft was constructed to specifications
  - Ensure safety of aircraft operator and passengers
  - Protect the public and environment from potential catastrophe
- Main Purpose: Protect society from aircraft unsuitable for flight

# Problem with Certification

- Expensive
  - Many requirements of unmanned systems based on manned systems though they are fundamentally different
  - Many regulations based on pass/fail basis of a requirement leaving little room for a fuzzy pass fuzzy fail.

# Why should unmanned certification be different?

- An unmanned system can crash with little risk to pilot or ground personnel
- A small unmanned system is the size of a baseball, while a small manned system is the size of a car
- For many systems a failure is acceptable within design limits; a pass/fail test does not accurately represent requirements

# Problem with Certification

- Airworthiness certification can be a subjective process based on risk, not a pass or fail criteria

Pass
or
Fail

Pass = 90%
Fail = 10%

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# SLAT Introduction

SLAT(System-Level Airworthiness Tool) is a tool developed by David A. Burke, Charles E. Hall Jr., and Stephen P. Cook for determining air safety requirements for UAS certification based on a set of inputs which can be utilized in various ways to assist with a UAS over its lifetime.

- Certification based on moving scale determined by crash risk
- Testing based on a safety score, not on a pass/fail basis
- Targeting of high risk component, avoiding unnecessary on low risk components

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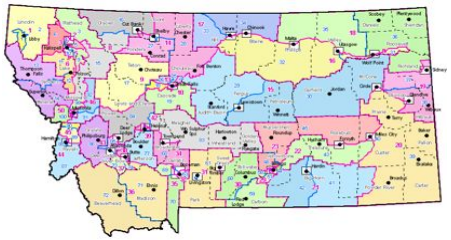
# Safety Score Calculation(TLS)

SLAT works by determining a Target Level of Safety (TLS) based on a vehicles crash damage risk, and area it will be flying.

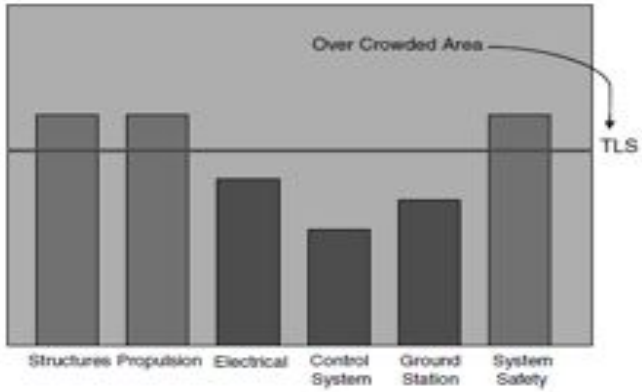
(w) Weight and (b) Wingspan

+



(p) Population density figures

=

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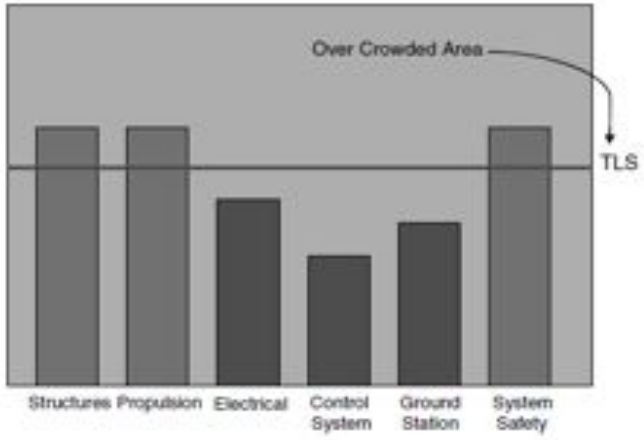
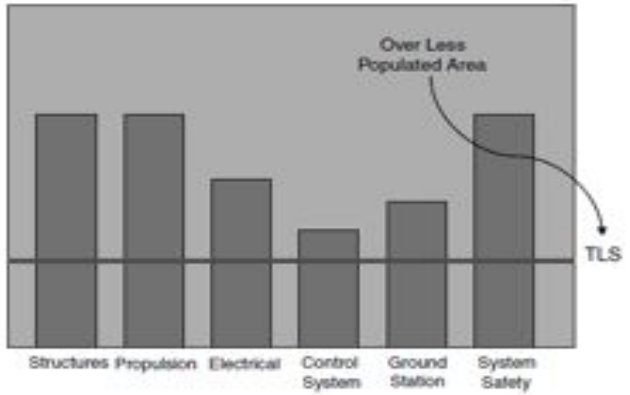
# Importance of TLS

This allows for UAS to be certified based on risk/ person, not based on a single non moving standard. This provides cost savings for low risk systems in which high costs would prevent use entirely.

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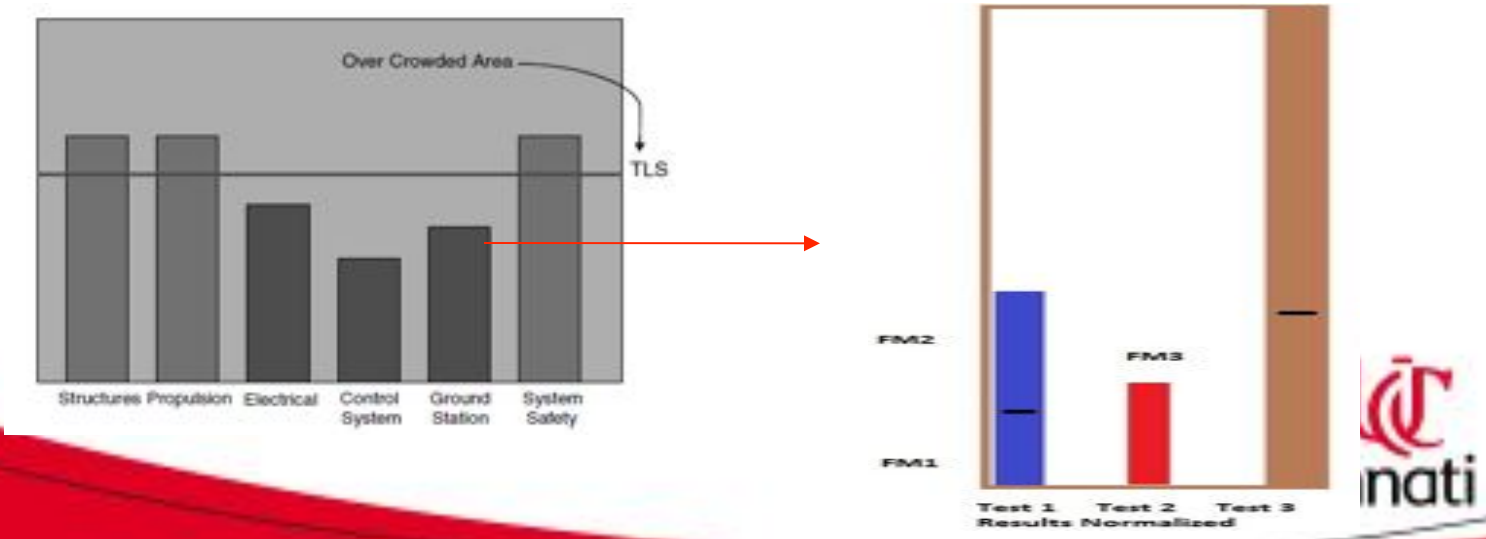
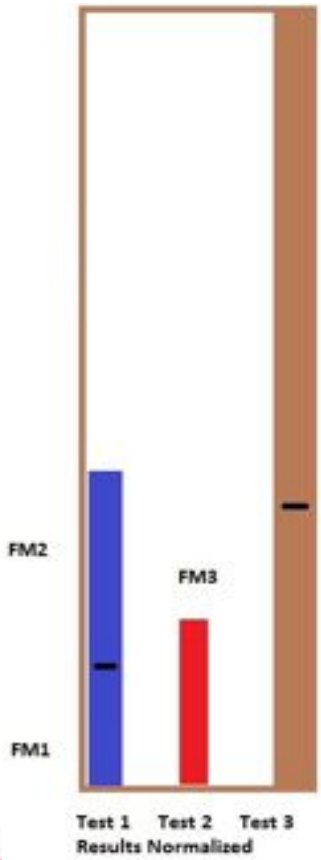
# TLS of a particular category

The Scoring works by analyzing a UAS in its 6 major failure areas. It then examines the failure modes of those areas. Testing of modes needs to support the needs of each area and be high enough to pass the safety score to be certified.



# TLS Calculation Components




| Failure Category | Criticality Scaling |
|---|---|
| Catastrophic | 1.0 |
| Critical | 0.8 |
| Major | 0.4 |
| Minor | 0.2 |

Failure mode Type and Number of failures


Failure Mode analysis

| | |
|---|---|
| Confidence= | 1 for Analytical Tests |
| | 2 for Physical Ground Tests |
| | 3 for Flight Tests |

Analysis of how well a Test verifies a requirement

| Quality Scaling | | |
|---|---|---|
| | Manned Eq. Verification Method | <Manned Eq. Verification Method |
| Manned Eq. Standard | 1.0 | 0.7 |
| < Manned Eq. Standard | 0.85 | 0.5 |

Mode Safety score is calculated by:

- Type of Test
- Failure Mode of Test
- Quality of Test

Does not address Repetitive testing or the Tiered (V Model) component testing

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# SLAT Tool Conclusions

-SLAT is effective at providing a certification standard based on moving risk.

- It can account for system level safety and component failure mode safety.

- Does not address repetitive testing or multiple test setups for computation as common in V Model.

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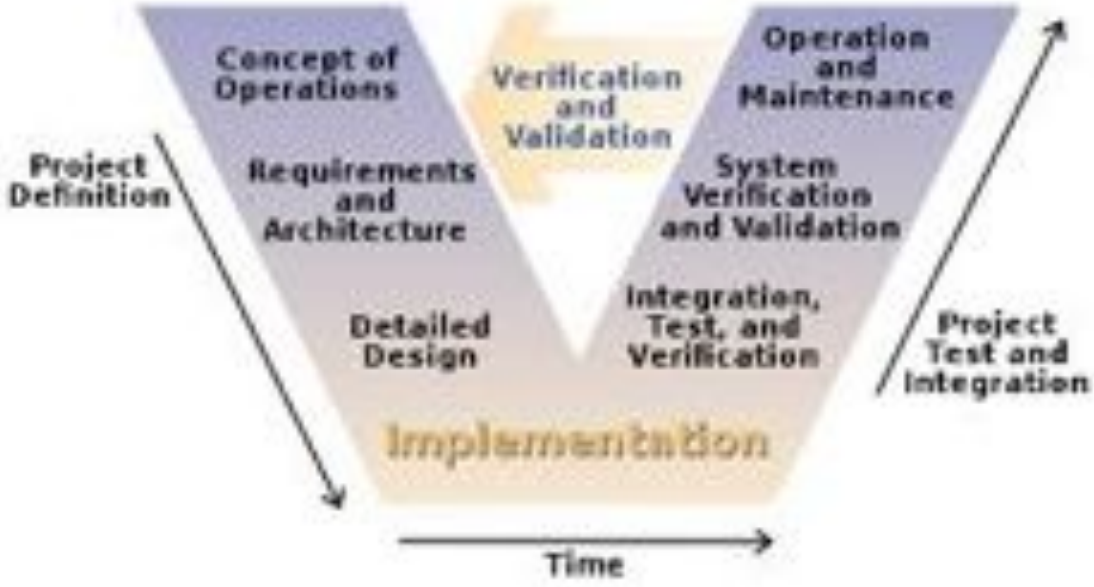
# Systems Engineering V

V Model is a Tiered Development/Test scheme which needs to be implemented into SLAT Tool




Full System Tests

Sub – System Tests

Component Tests (many are free)

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# Research Objective

- Use Fuzzy logic to add testing redundancy capabilities to SLAT and support tiered input structure
- Allows for less testing and takes advantage of the Systems Engineering V Model of development

# Fuzzy Logic Introduction

- A simple method
  - Compares vague ideas such as redundancy, and tiered testing relations
  - Accounts for multiple vague variables
- Drawbacks
  - Requires human adjustment and tuning to create a rule set

# Rule Set Creation

The rule set was based on practical assumptions by a human-based agent and simplified from the input scores into 2 mathematical inputs

| Redundancy | |
|---|---|
| How many times did we prove the result | Human Analysis |
| 1 | No increase in confidence |
| 2 | Slight Increase in Confidence |
| 3 | Increase in Confidence |
| 4 | Great Increase in Confidence |
| Above 5 | Very Large Increase in Confidence |

| Correlation of Quality of Test | |
|---|---|
| Are the values of the scores when added high? | Analysis |
| No | No increase in confidence |
| A little | Slight Increase in Confidence |
| More than a little | Increase in Confidence |
| Allot | Great Increase in Confidence |
| Absolutely Yes | Very Large Increase in Confidence |

Fuzzy was effective for combining these abstract inputs

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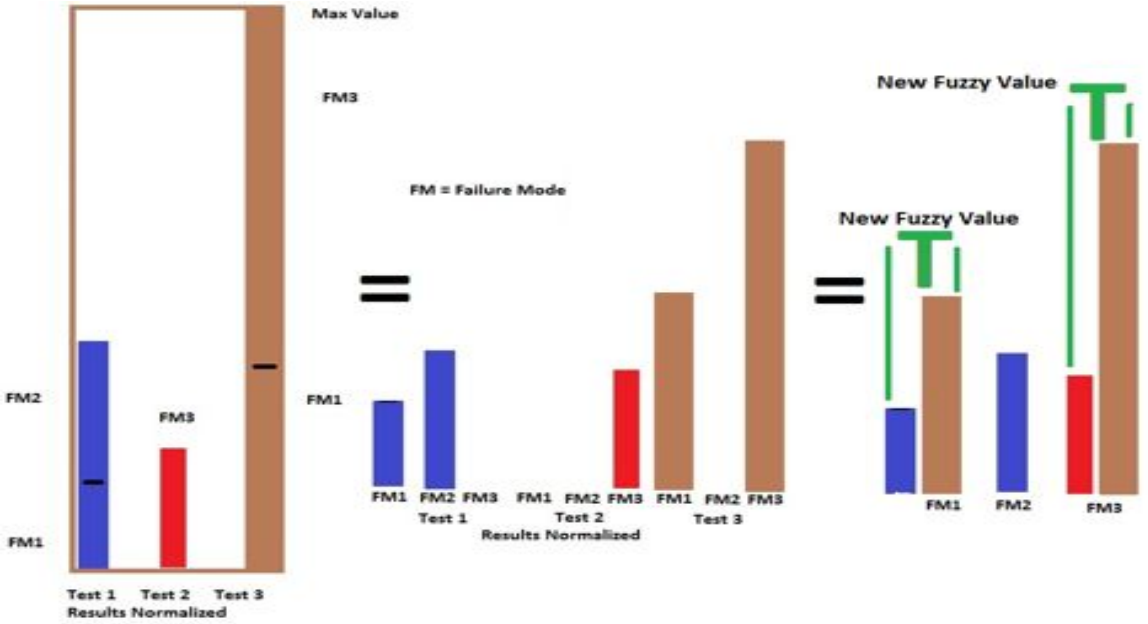
# Fuzzy Redundant Tests

The Fuzzy Tool works by analyzing a test for redundant results, and correlating their scores.

*Right – Test results are further analyzed by the fuzzy tool to be broken down beyond test and score.*

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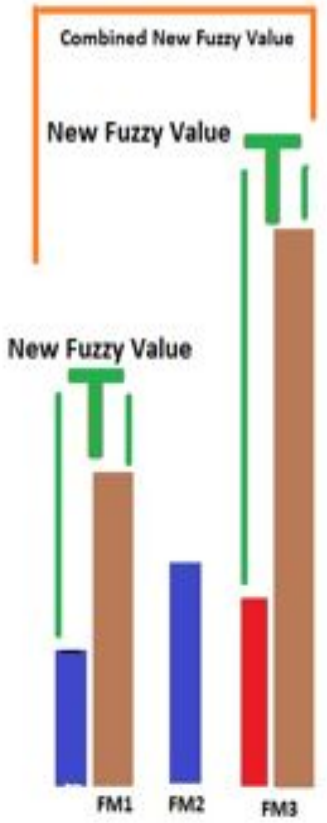
# Correlated Score Values

After conditions are tested for redundant performance, they are analyzed for correlating results of each condition tested to reproduce the new Test Score TLS Value



# Examples

System under development using V Model inherently provides 10 free component tests, and 3 free sub-component tests.

Will system survive to 100 flight hours over a desert?

- Normal Certification – Fly 5 Full systems to 100 hours without incident
- SLAT Tool – Fly 1 Full System 100 Flight hours
- SLAT Fuzzy Tool – Combine 10 component tests of 100 hours, with 5 subsystem tests of 20 hours, with 1 Full System Test to 10 hours

# Testing Costs

Component Test = $10/hr

Sub System = $100/hr

Full System Test = $500/hr

| Test | Total Cost |
|---|---|
| Normal Certification | 250000 |
| Slat Tool | 50000 |
| Slat Fuzzy Tool | 9000 |

# TLS Input

## Fuzzyrun.m MATLAB

```
Can handle from 2 to 5 tests per failure mode
Please enter TLS values of failure mode: (format as [value value value] [34 56 4]

ans =

   69.4235

>> a

a =

           name: 'FuzzyRunfile'
           type: 'mamdani'
      andMethod: 'min'
       orMethod: 'max'
    defuzzMethod: 'centroid'
      impMethod: 'min'
      aggMethod: 'max'
          input: [1x2 struct]
         output: [1x1 struct]
           rule: [1x9 struct]
```

Previous SLAT Tool would have resulted in TLS Value of 56, but accounting for this condition being proven by 3 tests, with 2 relatively high TLS values, we can improve the overall TLS Value to 69 with the Fuzzy Tool.

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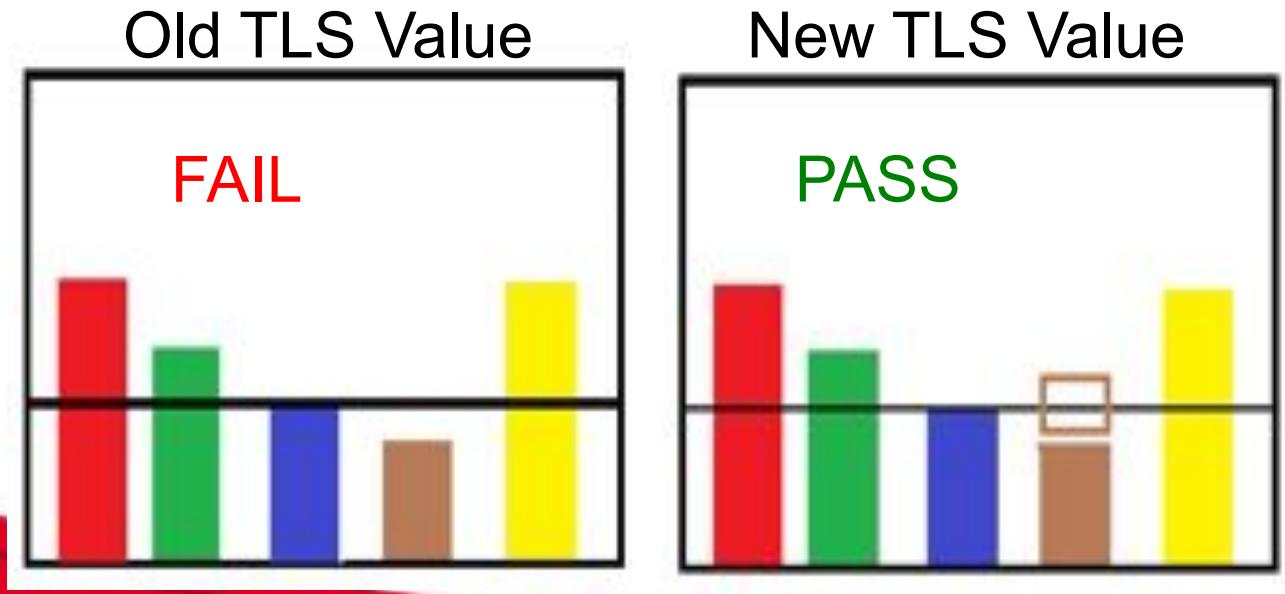
# Conclusions

By accounting for test redundancy and correlating data, we can gain more accurate results for certifying UAS, preventing unnecessary testing, and unnecessary costs.



Questions?

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# References


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- “System-Level Airworthiness Tool”, David A. Burke∗ and Charles E. Hall Jr.† North Carolina State University, Raleigh, North Carolina 27695 and Stephen P. Cook‡ Naval Air Systems Command, Patuxent River, Maryland 20670. JOURNAL OF AIRCRAFT, Vol. 48, No. 3, May–June 2011


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