Joint Air Defense Operations – Homeland (JADO-H)

Survey Analysis Using Fuzzy Logic

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Overview

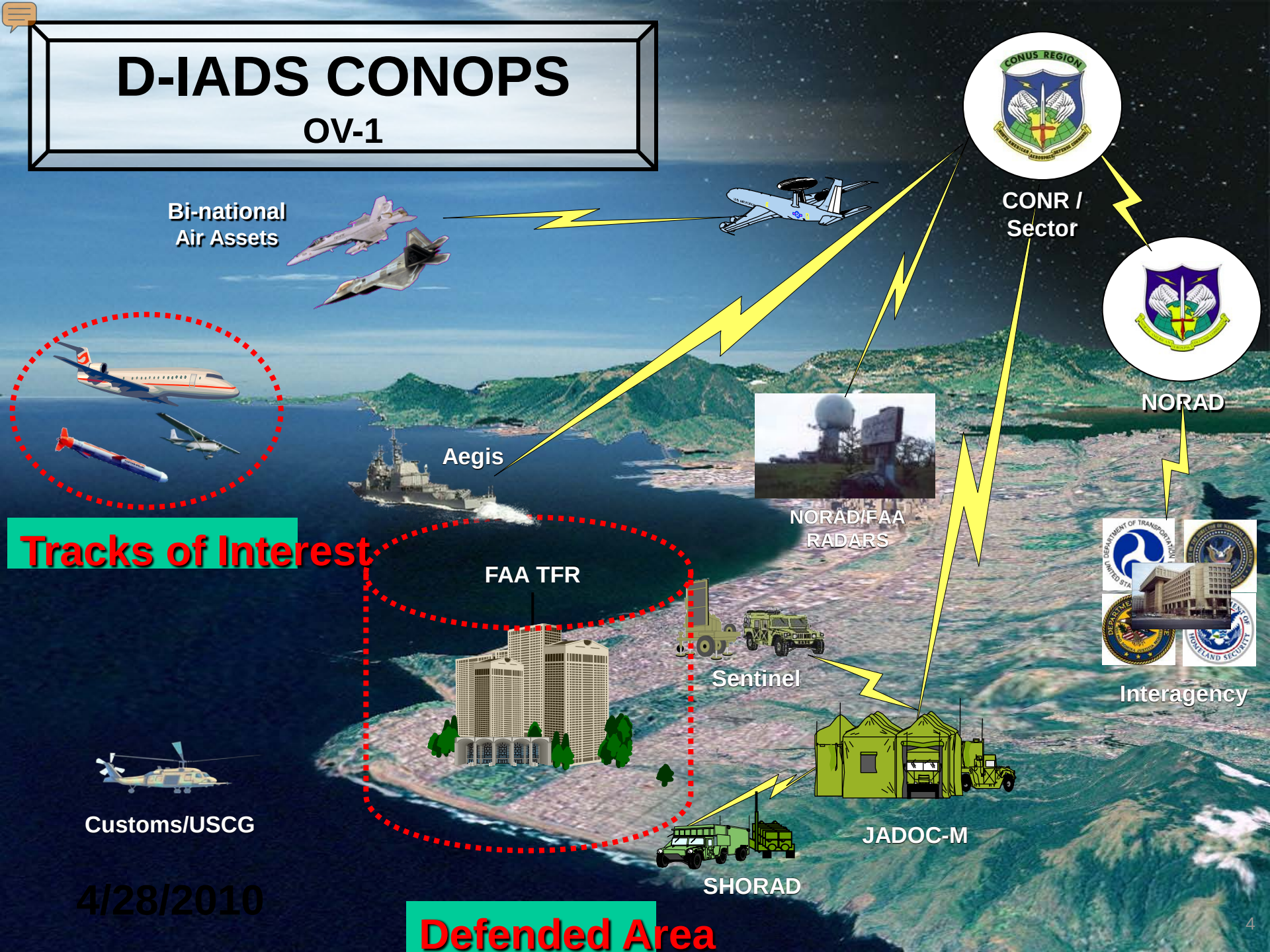
- Our Client
- Problem Statement
- The Data
- Model/System Development
- Analysis and Recommendation

The Client

- JADO-H is a joint test designed to develop the TTP's (Tactics, Techniques, and Procedures) for the deployment of air defense assets in the CONUS.
- Funded for 3 years - once complete, test group is disbanded.
- JADO-H tasks
  - Create TTP's
  - Conduct Exercise using TTP's
  - Received feedback from war fighters on the ground
  - Update TTP's based on feedback
  - Conduct final exercise this summer in May.
- All client/organizational info was provided by client.

D-IADS CONOPS

OV-1



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Problem Statement

- JADO-H provided us with a model using a new concept called multi-level fuzzy logic.
  - Converts survey results about TTPs into 1 final output to measure the total effectiveness of the TTPs.
- We are tasked with determining why the JADO-H fuzzy logic model is converging.
  - JADO-H is not concerned with us developing another model.
  - Only wants to know why current model is failing and if it is fixable.
- Possible Impact/Deliverable
  - At this point it appears model can be improved slightly, but not to desired standards.
    - Methods to change convergence help with justification.
  - This will prevent others from using a similar process in the future or identify where it can be improved.

Deliverables/Impact

- If we:
  - Conclude that the JADO-H model works:
    - Written Recommendation/Working Model
    - Could be used throughout the Joint-Test Community and the military as a whole to interpret survey results in the future.
  - Conclude that the JADO-H model does not work:
    - No longer an option to interpret this data
    - Provide written report on source of failure
- Bottom line:
  - Our project has real world impact!

The Data

- The model is designed to accept a set type of data inputs.
  - 3 teams (red, blue, green) of 4 people each responding to 6 questions for a total of 72 data points
  - Each data point is a value from 1-6

Example survey excerpt

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D-HACMD Planning TTP Survey

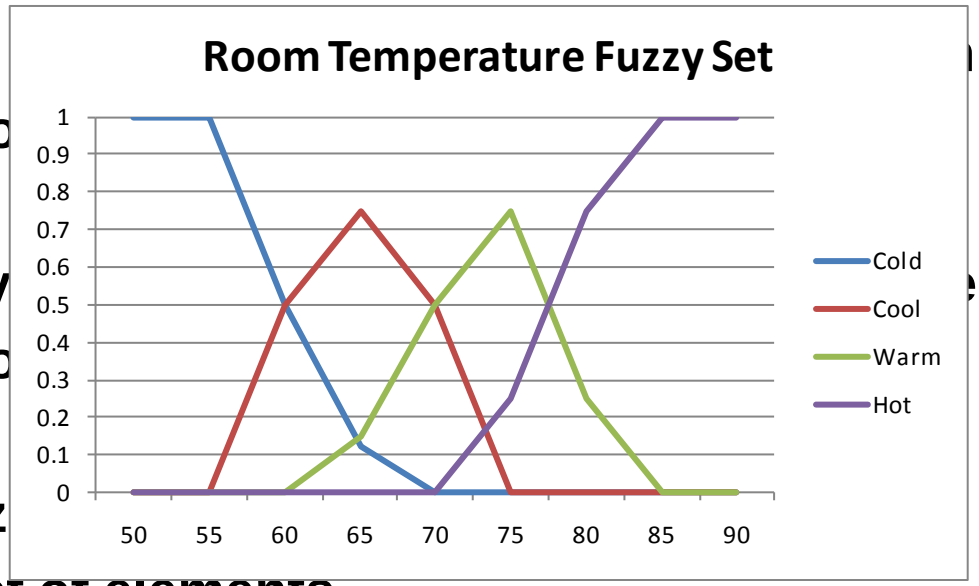
1. Please rate the completeness of the JADO-H developed TTP in supporting development of the plan identified on page 1 in the following areas:

	Negative Responses			Positive Responses			
	Unacceptable	Poor	Marginal	Fair	Good	Excellent	N/A
a. Topics	1	2	3	4	5	6	
b. Coordination Info	1	2	3	4	5	6	
c. Other Information	1	2	3	4	5	6	NA

The Data - continued

- Our focus is to *fix the model*, not interpret the data, therefore data will be simulated.
  - This is to ensure model stability and accurate data interpretation under a variety of circumstances.
  - Original data is from surveys, this influences structure of the model, but not structure of the data inputs.
    - All data is a number from 1-6, the model converts this to a fuzzy logic graphical representation.
    - Therefore simulated data is only a random or manual number generation from 1-6 for all 72 inputs.

Fuzzy Logic Introduction

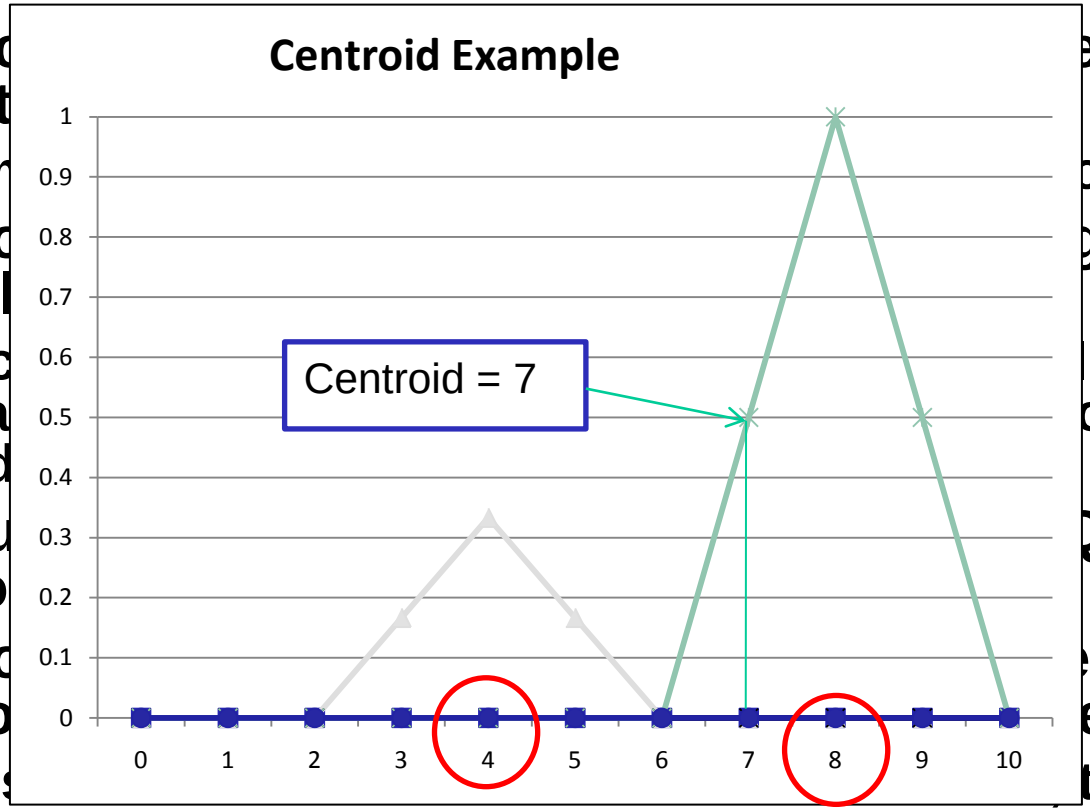


- Crisp … its meaning.
  - Ro…
- Fuzzy … eness.
  - Ro…
- A Fuz…
  - set of elements.
  - membership function (tells amount each element belongs to set).

- Uses rule-based systems for decision-making.
  - If controlling a thermostat: if temp = Hot, then set A/C = On.

The Model

- Each c… esponse) fits into at…
  - Sor… ool”).
- Centro… g all the fuzzy l…
  - Eac… lies (in above exa… old” curve and…
- For ou… Question 1 are co…
- Centro… ed with centro… estions.
  - This… this time determined by rules which relate all the fuzzy logic curves.



The Rules

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	x'	poor	marginal	good	excellent
Question 5	8	0	0	1	3
Question 6	8	0	0	1	3

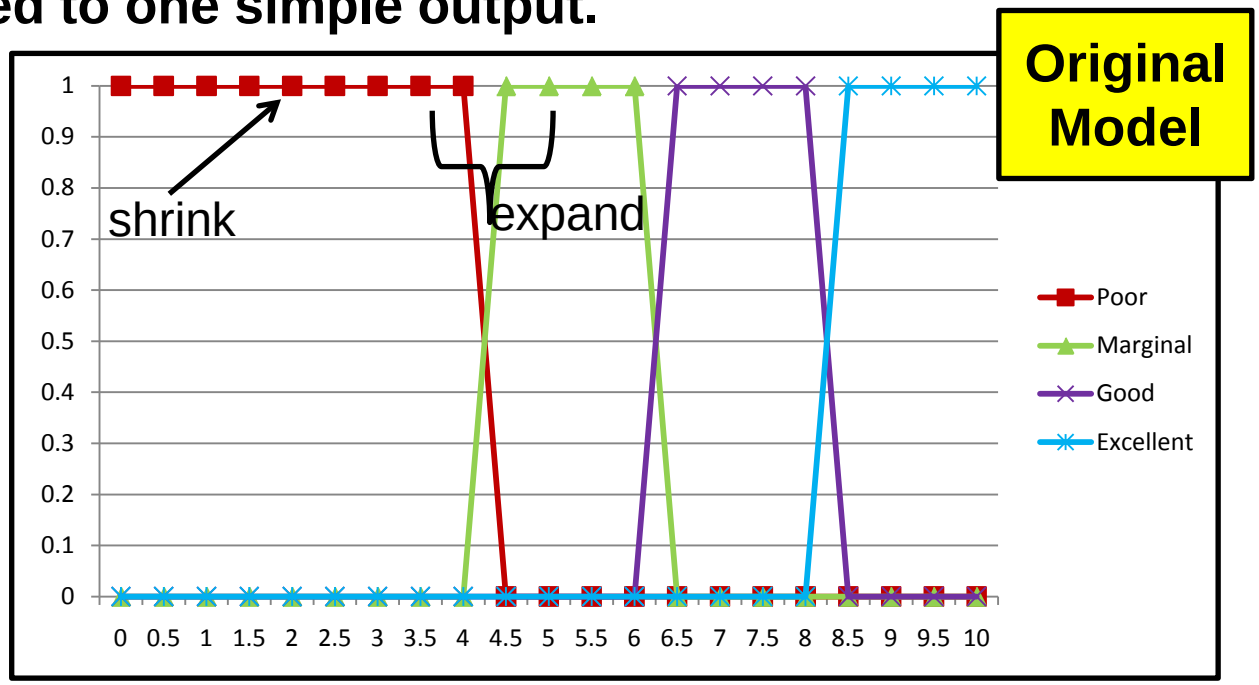
Level of Detail	Understandable	Min	Usability
0	0	0	poor
0	0	0	poor
0	1	0	marginal
0	3	0	marginal
0	0	0	marginal
0	0	0	marginal
0	1	0	marginal
0	3	0	marginal
1	0	0	marginal
1	0	0	good
1	1	1	good
1	3	1	good
3	0	0	good
3	0	0	good
3	1	1	excellent
3	3	3	excellent

results

Max(poor)	0
Max(marg)	0
Max(good)	1
Max(excellent)	3

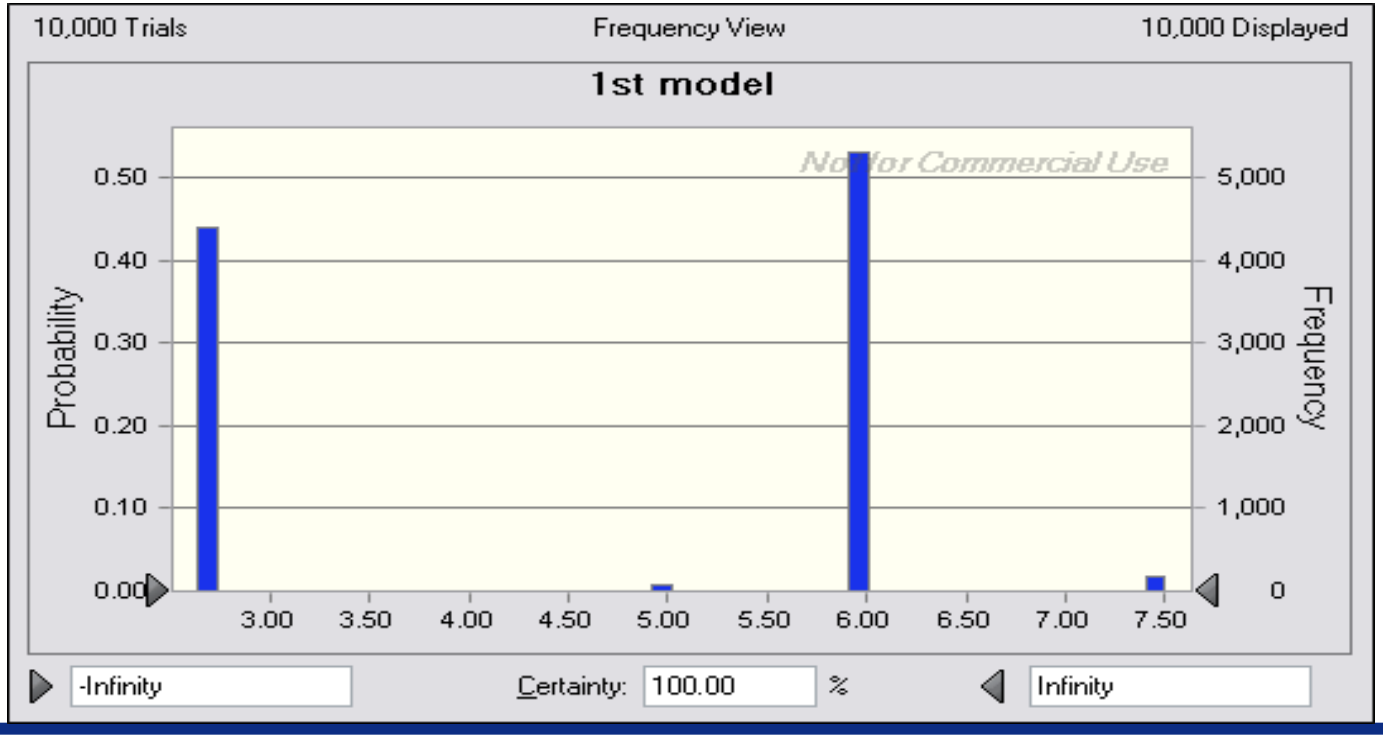
Model Alterations

- The fuzzy sets from which the percentages are determined via the centroid have very large plateaus – resulting in 100% “poor”, “marginal”, etc. as shown in original model’s fuzzy set definitions below.
  - We believe this is the cause of the convergence, since each level is typically rounded to one simple output.
  - We attempted to shrink these plateaus and expand the valleys in-between.



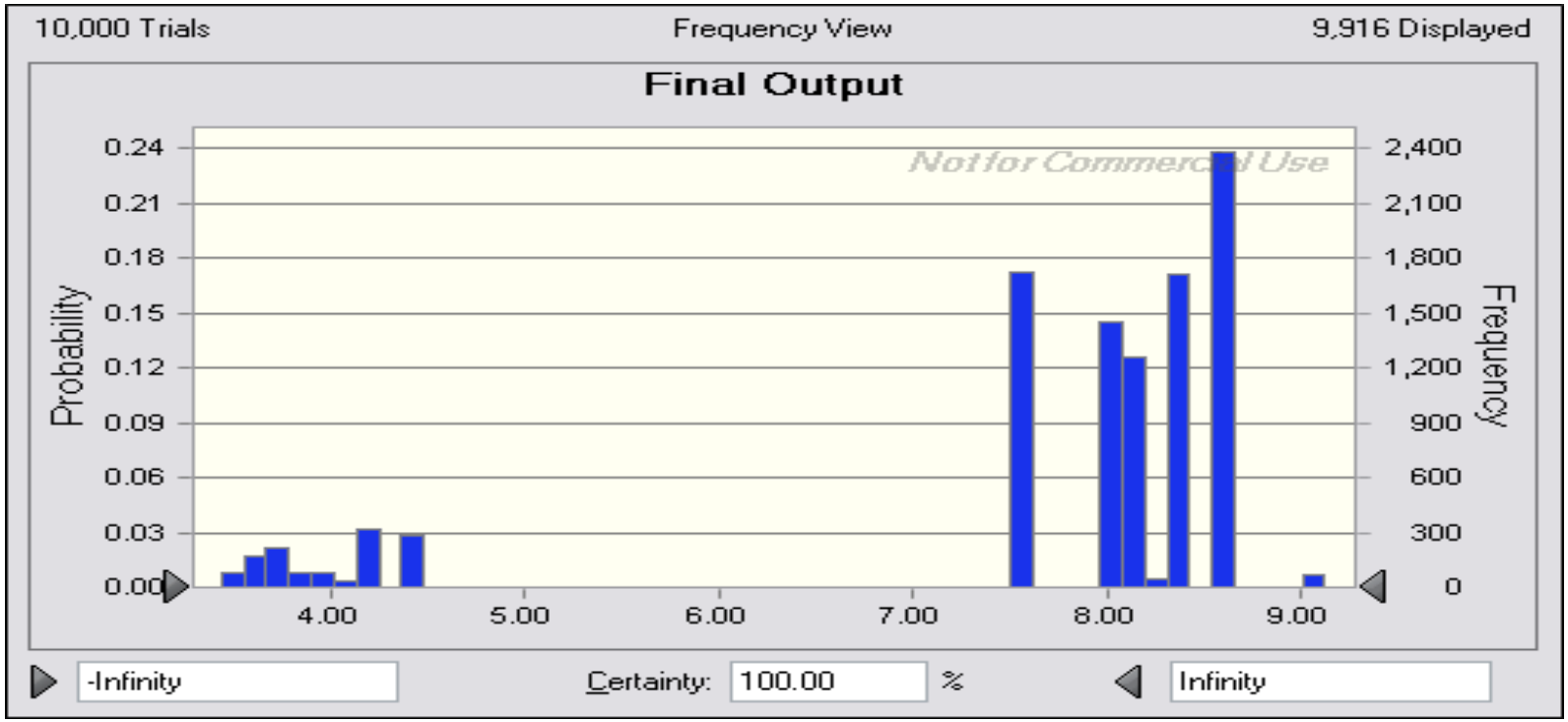
Baseline comparison

- Using Crystal Ball, we created a custom distribution to try and reflect actual survey results.
- Shows convergence when input into the original JADO-H fuzzy logic model - which we think is caused by the plateaus.



Initial Results of Model Alteration

- In the first model alteration, the goal was to keep JADO-H's general definition of the fuzzy sets, "poor", "marginal", etc.
- Using the same survey data distribution, the altered model shows less convergence, and confirms our hypothesis that the plateaus are one possible cause of the problem.



Initial Hypothesis

- The convergence in the original model can be decreased, but it is still flawed.
  - Fuzzy logic takes crisp or “certain values” and classifies them with a degree of uncertainty.
  - The model takes fuzzy values - the curves - from the previous step and makes them a more certain crisp value.
  - This is a backwards process that derives certain responses from uncertain values.
  - This certainty is heavily weighted by the rules, which then creates convergence.
  - The greater the instances of certainty (100% good is more certain than 60% “good”, 40% “average”) the more the rules will affect the resultant value and the more convergence will take place.

Conclusion and Where We Go

- Original model is wrong, but can be improved by reducing the amount of certainty derived from uncertain values the level before.
- We need a more thorough justification of why the original model is theoretically wrong, this will utilize analysis of improvements as evidence to support our claims.
- We will continue to alter the inner workings of the model while keeping the main processes the same.
  - Small changes we make in the system can have a much larger effect than anticipated, such as changing rules and altering fuzzy set definitions.

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Questions?