June 2007

The PRIM: Extracting Expert Knowledge For Aiding in C2 Sense & Decision Making

Hudson Graham, Gilles Coppin, & M. L. Cummings
MIT Humans & Automation Laboratory

- **Introduction**
  - Problem identification
  - Design considerations
  - Usability Scenario
- **PRIM: A possible solution?**
  - Gathering expert knowledge (Input)
  - Processing expert knowledge (Output)
- **Benefits**

- **Today's Command & Control (C2) environment**
  - **Rapid and continual information**
  - **High volume, high tempo and uncertainty**
- **Need to help battlefield command synthesize information for action**
  - **Accurately capture experts' decision making processes via a computer interface**
  - **Encourage intra-team collaboration to a common solution**
- **The Probability & Ranking Input Matrix (PRIM)**
  - **Allow experts to input effect and likelihood of occurrence of a variable, as well as variable importance in deciding on one course of action.**
  - **Test PRIM with a hypothetical walk through.**

- **"Skilled problem solvers and decision makers are chameleons…can simulate all types of events and processes in their heads" (Klein, 1999)**
- **Humans:**
  - **Poor statisticians (Clemen, 1996; Kahneman & Tversky, 1979; Wiener & Nagel, 1988)**
  - **Only process through a few alternatives when thinking about solutions (Gigerenzer, Todd, & Group, 1999)**
  - **Do not process through all attributes when making a decision (Slovic, Fischoof, & Lichtenstein, 1978; Wiener & Nagel, 1988)**

Design Considerations

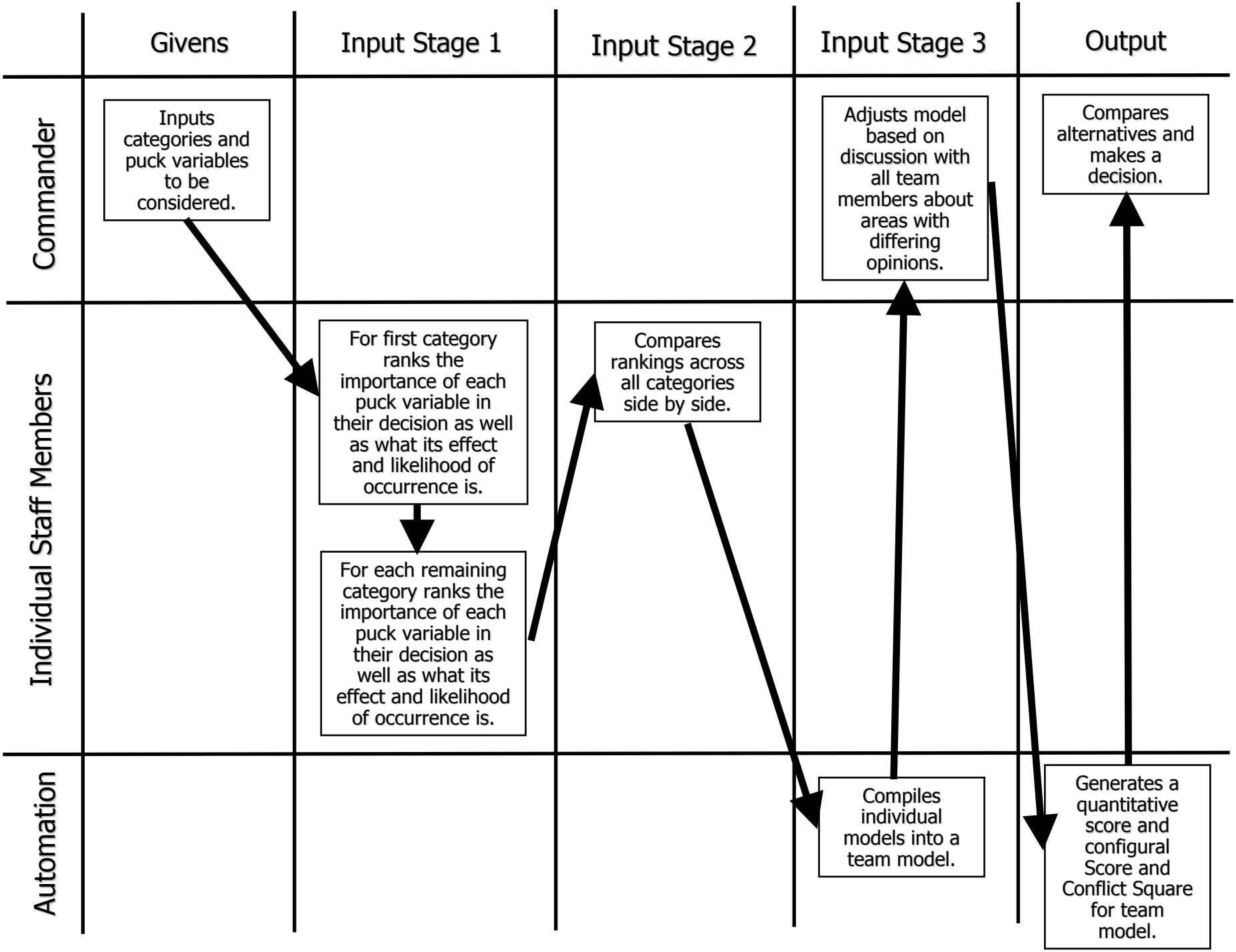
- **Experts:**
  - **Quickly categorize and act from these categories (Wiener & Nagel, 1988)**
  - **Typically assign variables into 3 to 4 categories and work from there (Klein et al., 2004)**
  - **3 advantages (Clemen, 1996):**
    - **Specialized knowledge**
    - **Make many forecasts**
    - **Receive immediate feedback**
- **No added accuracy for models with greater than 10 variables, just greater confidence in decision. (Wickens, Lee, Liu, & Becker, 2004; Oskamp, 1965)**
- **Teams:**
  - **Collective conscious (Klein, 1999)**
  - **Social dimensions (Gigerenzer, Todd, & Group, 1999; Klein, 1999)**

Scenario

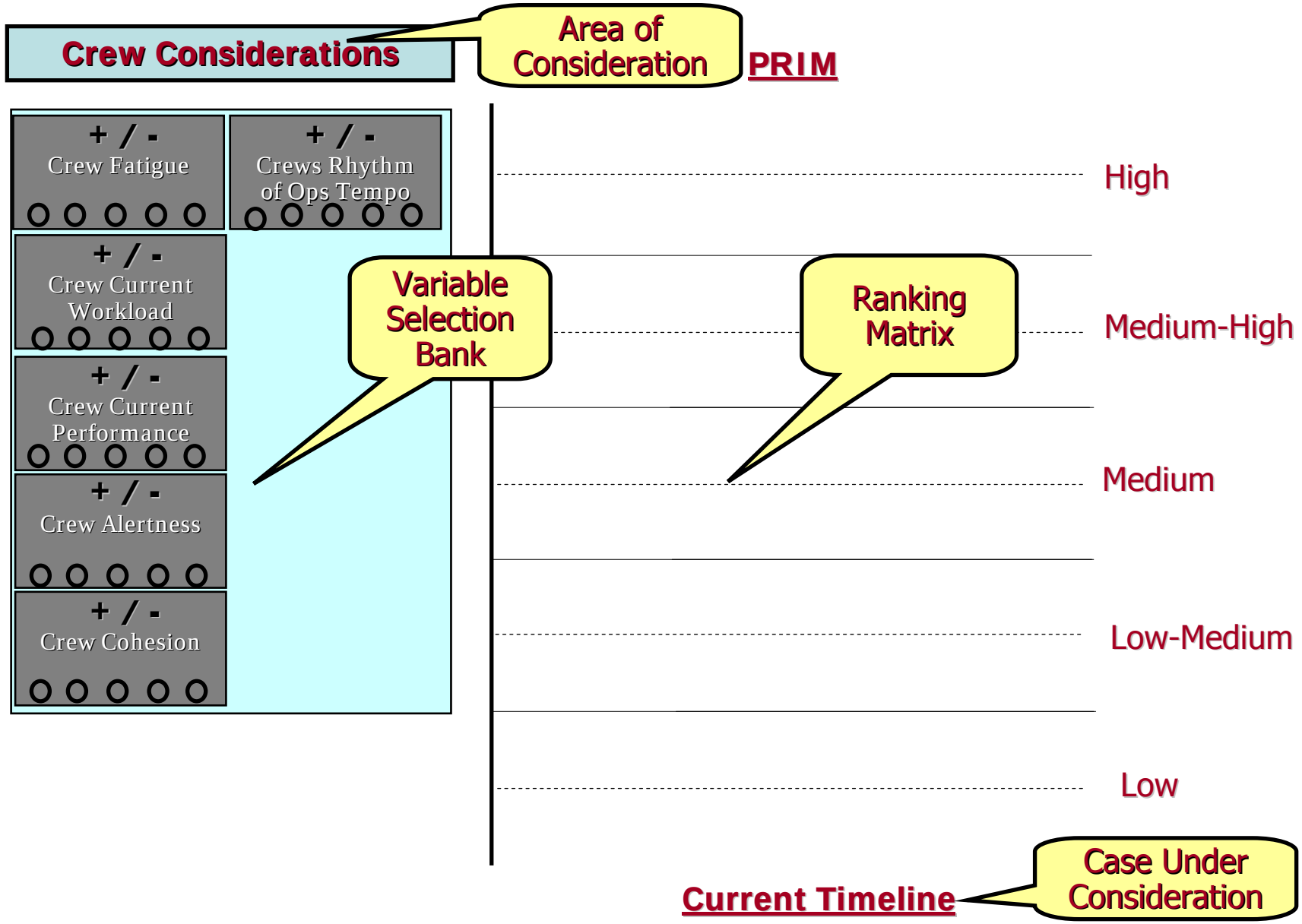
- You are a member of an Air Force battle staff that must decide if a mission for tomorrow should launch as scheduled or be delayed a day.
- Your staff has 3 hours to make the decision.
- The mission is to bomb and destroy 3 key industrial factories supporting the re-supply of the enemy's Unmanned Drones. These Drones are linked with the enemy's ability to maintain 24/7 surveillance of your troop movements.
- Your commander has given you a list of key variables classified into 3 categories he believes they should be considered within.
    - the crews' readiness
    - the aircraft & munitions' readiness
    - the target
- Your commander wants you to input the importance and likelihood of the variables' positive or negative influence on the outcome.
- You should complete this for all proposed courses of action (the current timeline and the delayed timeline).

- Notes to be aware of:
  - Your crews have been working 12 hour shifts, 7 days a week since the war began 6 weeks ago.
  - The weather is forecasted to be overcast with scattered thunderstorms for the next 18 hours. The clouds may block the precision munitions. After the thunderstorms, it is forecasted to be clear blue skies for the next week.
  - Over the last 7 days 95 percent of all missions have been deemed a success (the set targets/objectives were achieved).
  - Currently 30 percent of your aircraft are inoperative. Half of those aircraft have gone in the shop in the last 3 days.

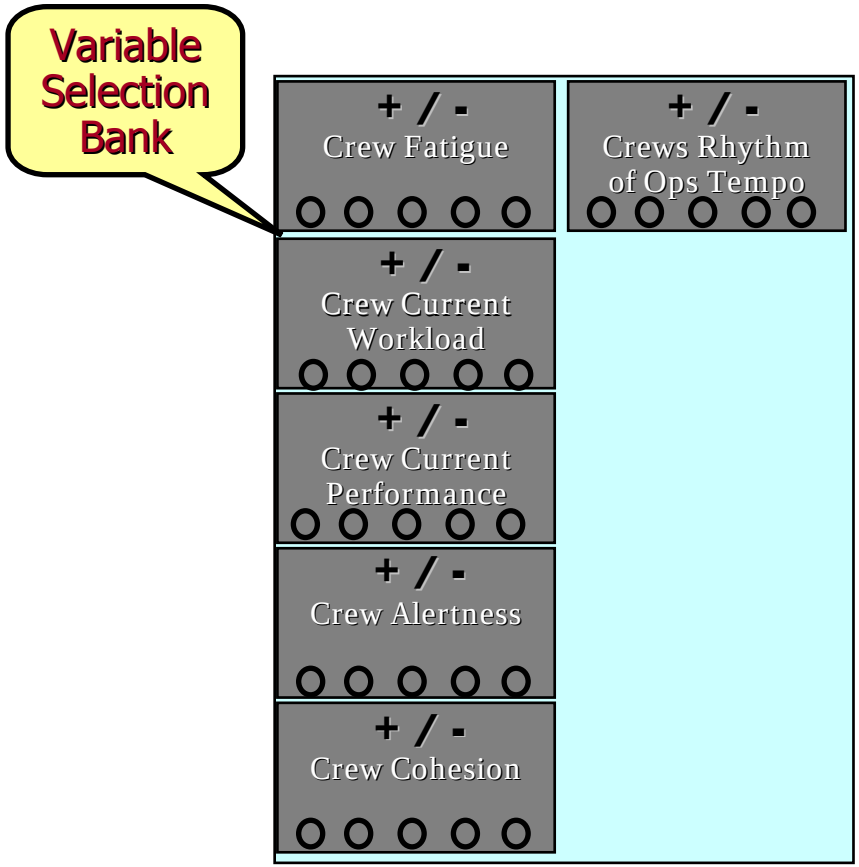
http://content.answers.com/main/content/wp/en/thumb/e/ea/250px-050903-N-6046R-001.jpg

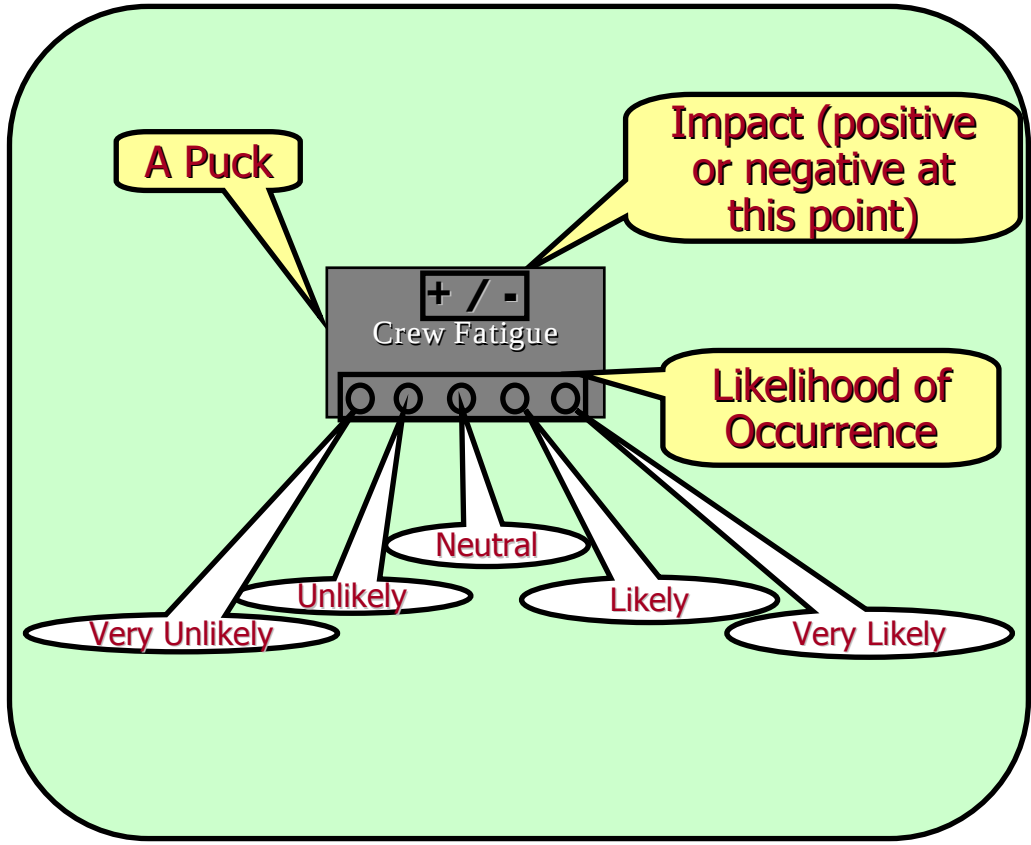

Givens
Input Stage 1
Input Stage 2
Input Stage 3
Output
Commander
Individual Staff Members
Automation
Inputs categories and puck variables to be considered.
For first category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
For each remaining category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
Compares rankings across all categories side by side.
Compiles individual models into a team model.
Adjusts model based on discussion with all team members about areas with differing opinions.
Compares alternatives and makes a decision.
Generates a quantitative score and configural Score and Conflict Square for team model.

PRIM: The Components of PRIM

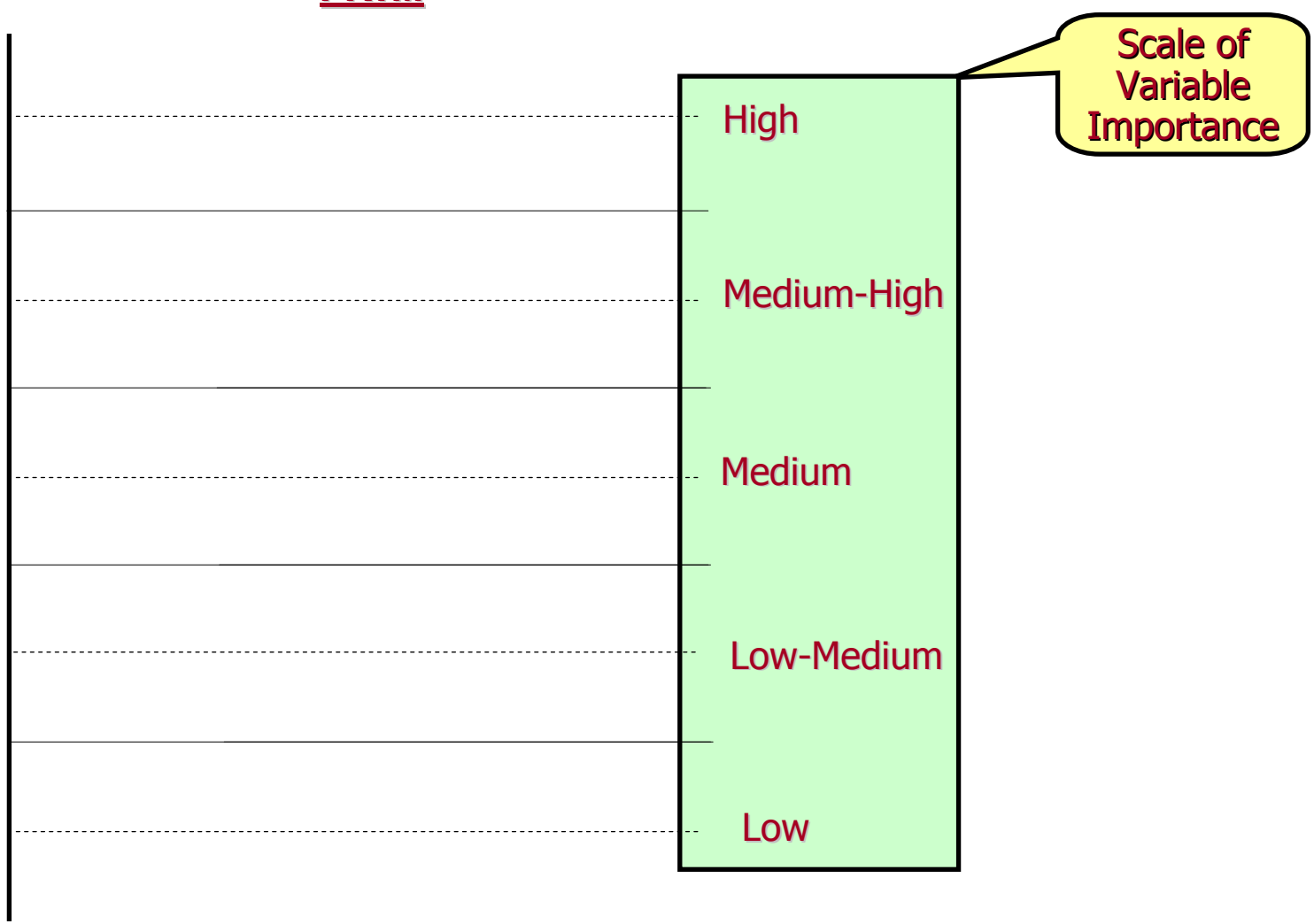


PRIM: The Pucks





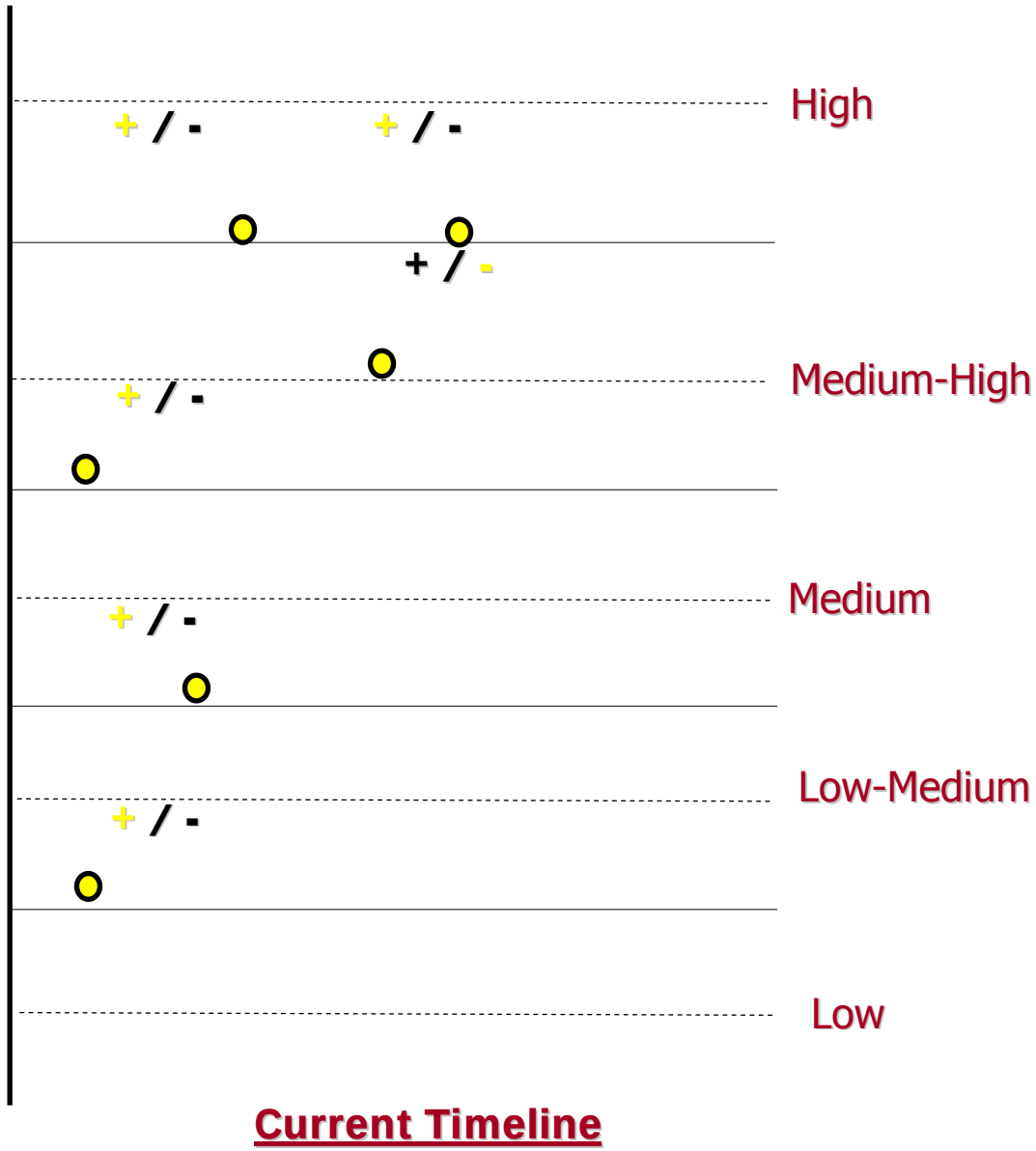
PRIM: Ranking Matrix



PRIM: Application of Individual Considerations

Crew Considerations

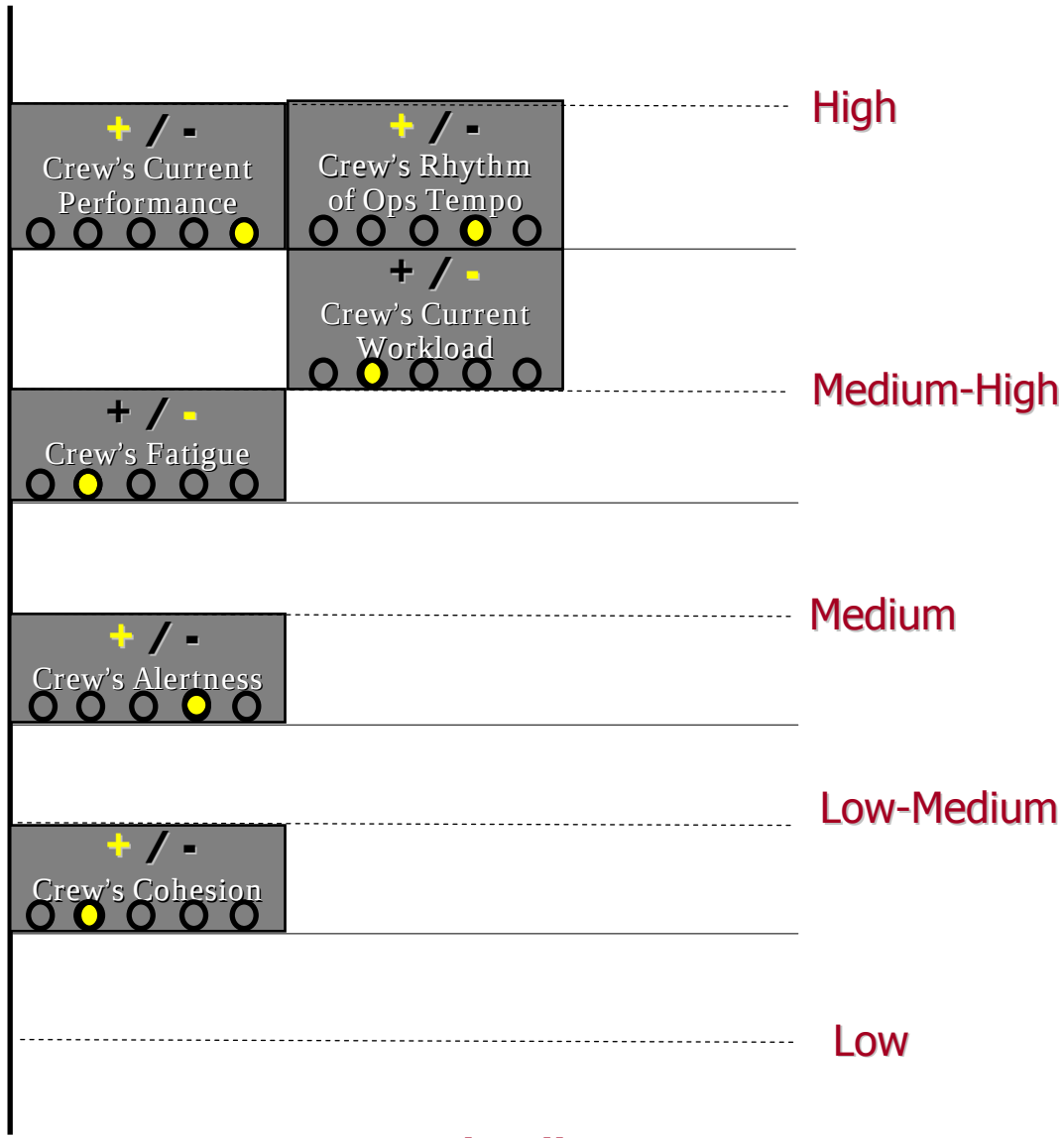
- + / - Crew's Current Performance
- + / - Crew's Cohesion
- + / - Crew's Rhythm of Ops Tempo
- + / - Crew's Current Workload
- + / - Crew's Fatigue
- + / - Crew's Alertness



PRIM: Application of Individual Considerations

Crew Considerations

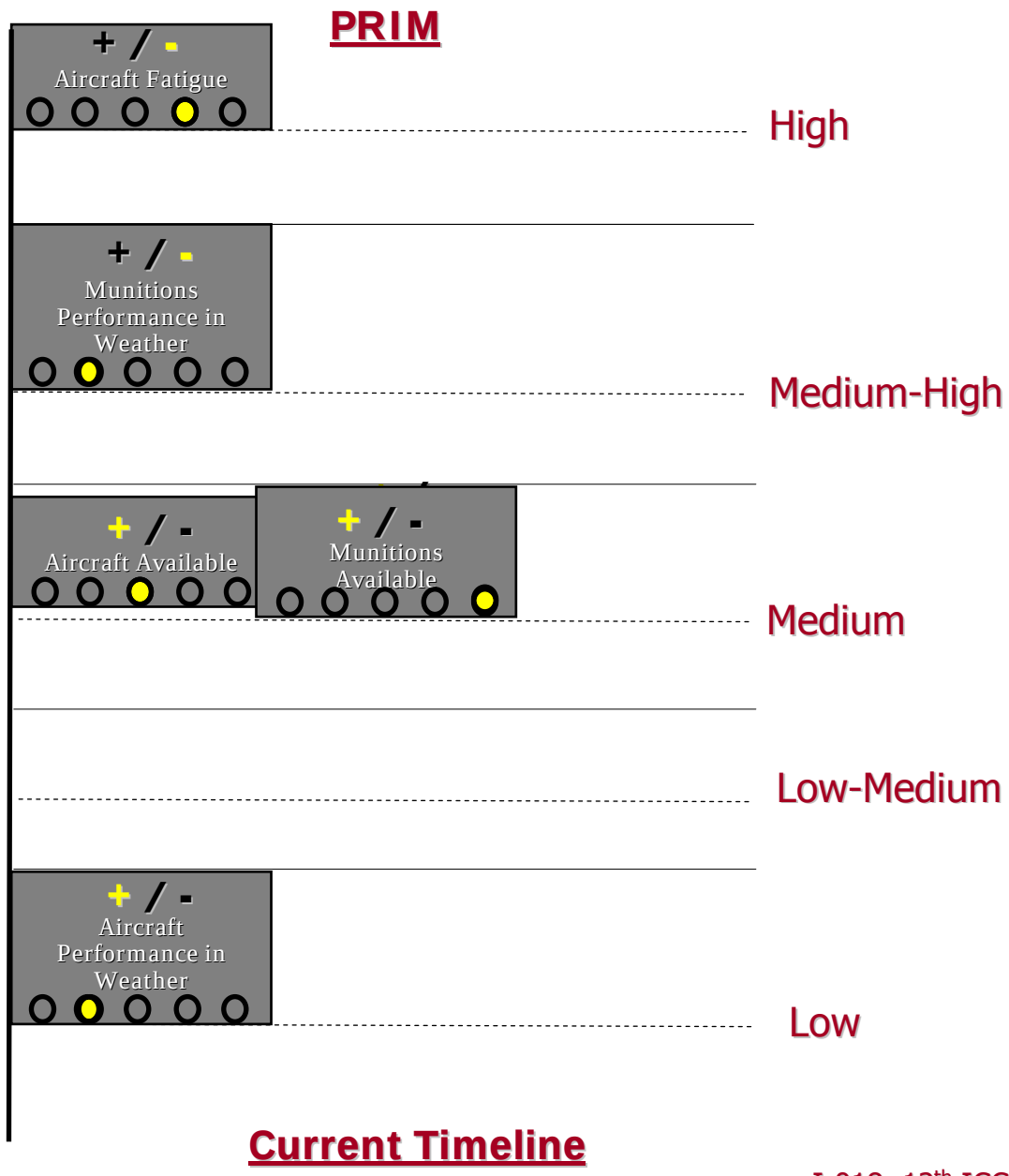
PRIM



Current Timeline

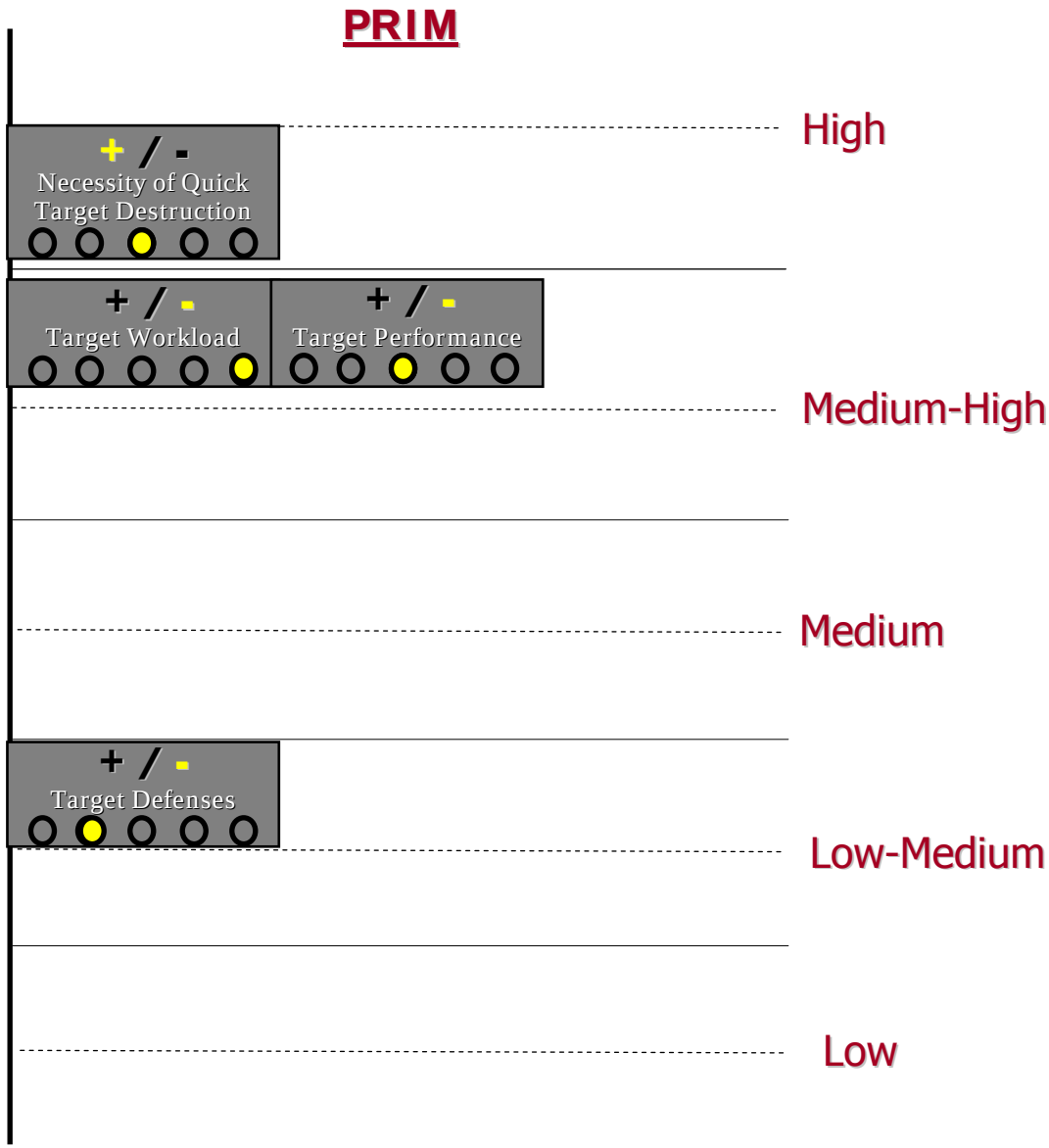
PRIM: Application of Individual Considerations

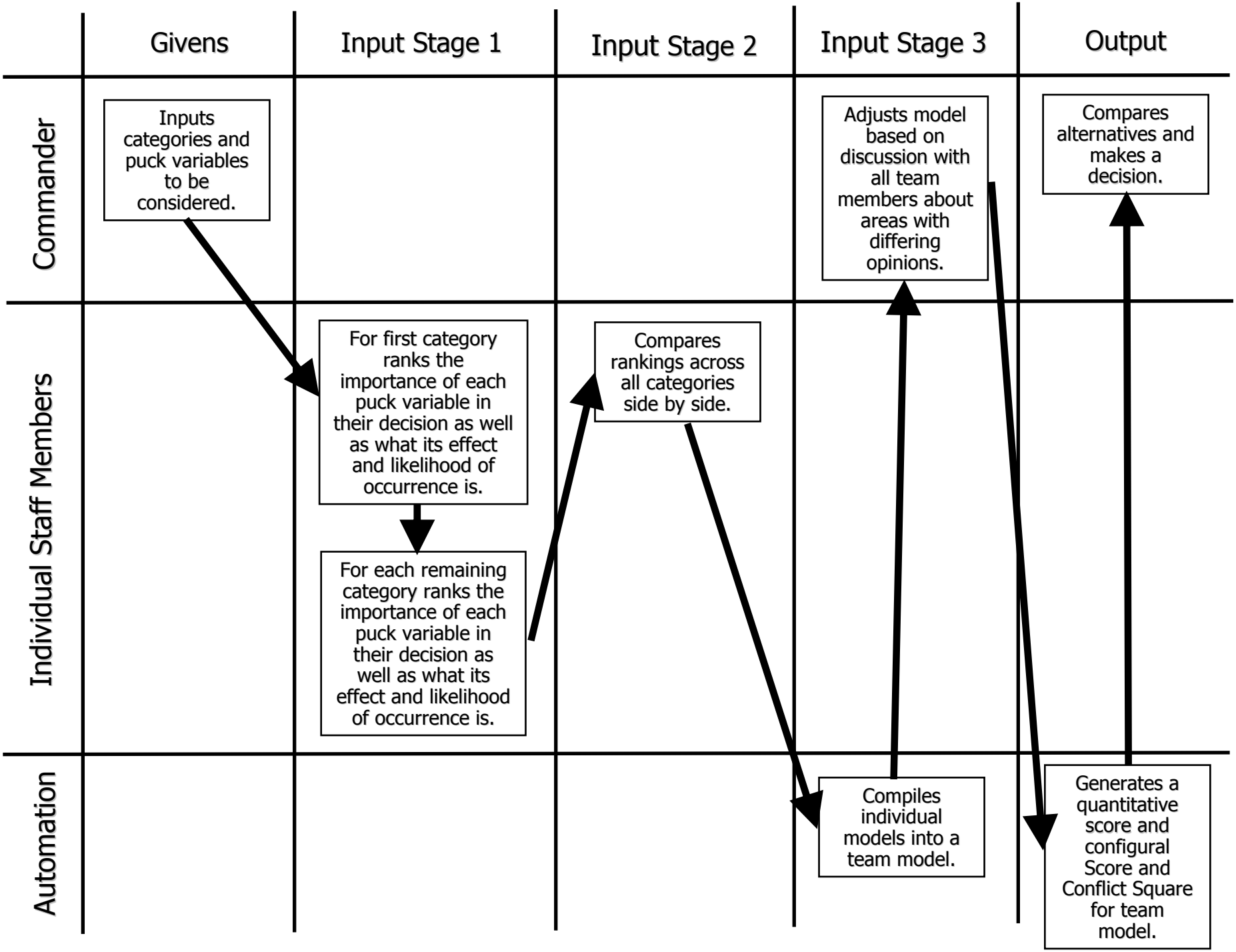
Aircraft / Munitions Considerations

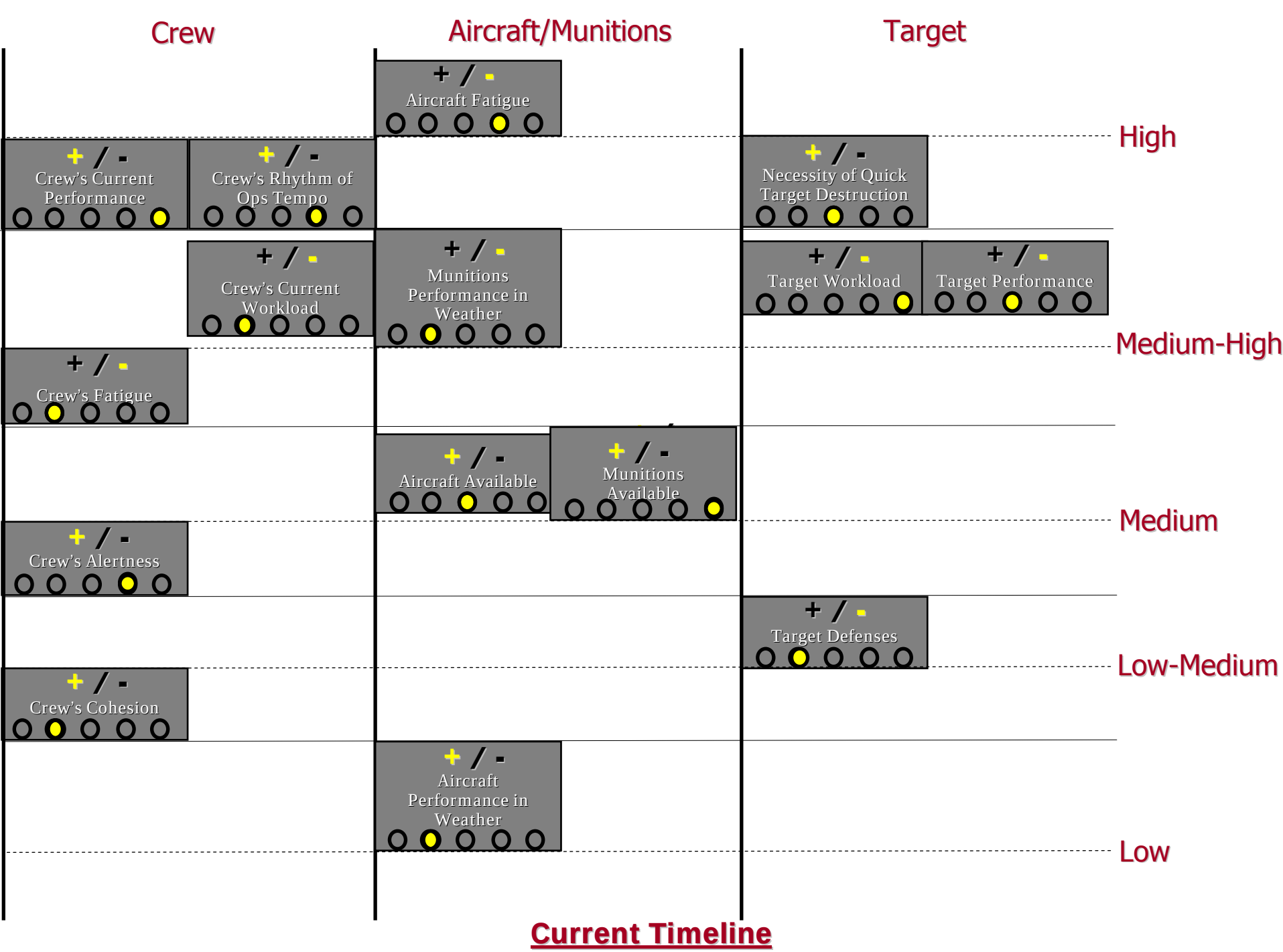


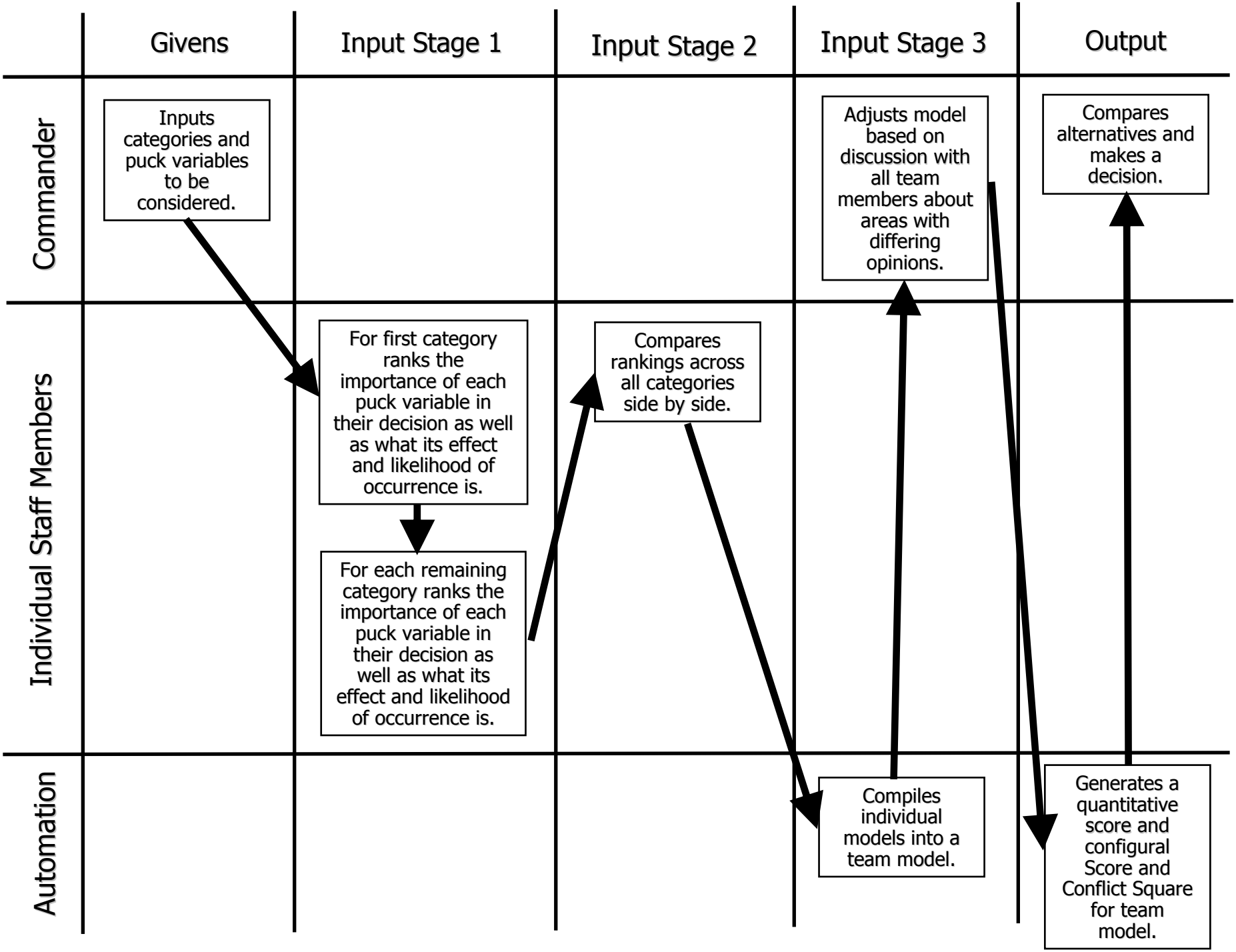
PRIM: Application of Individual Considerations

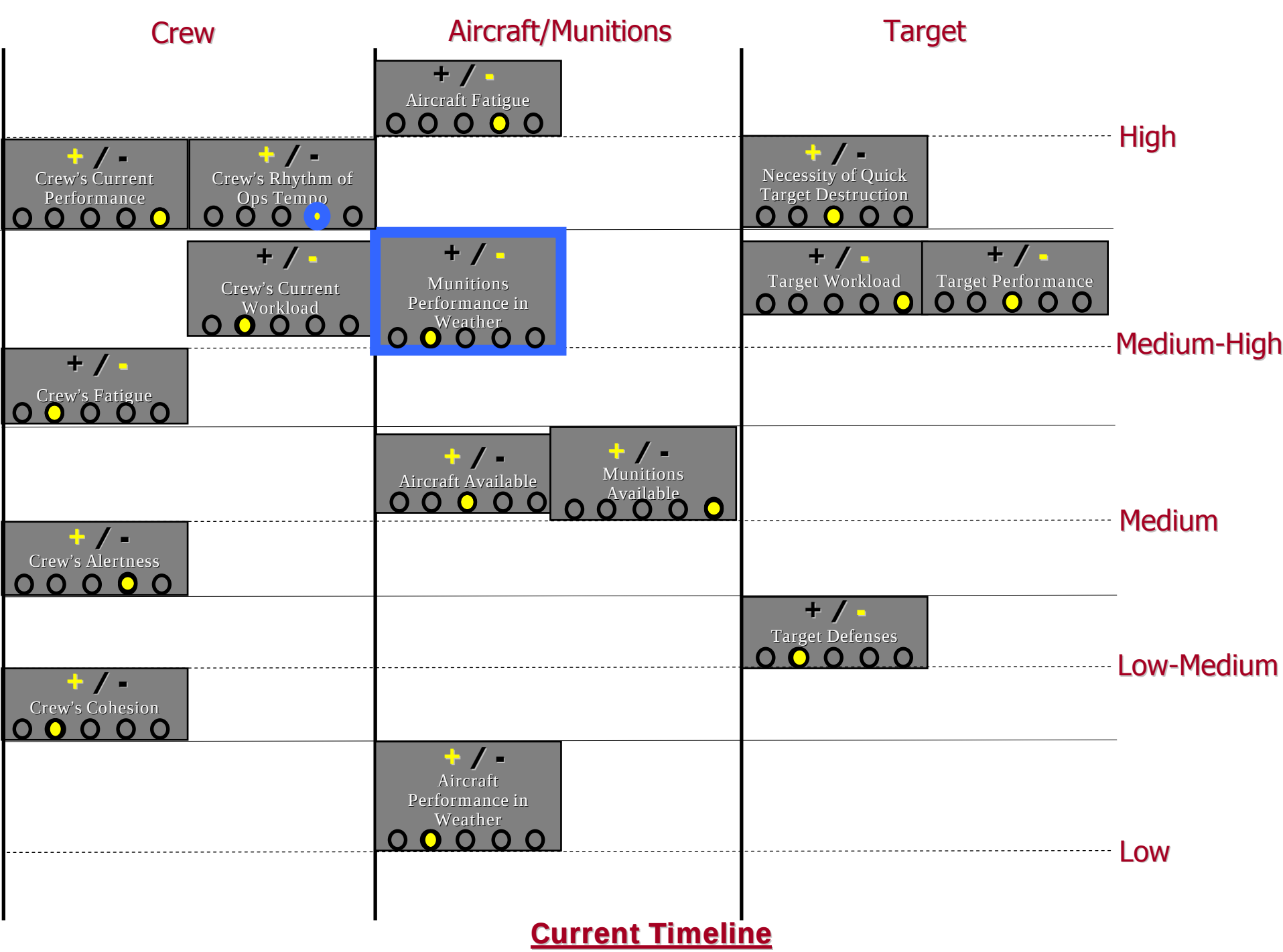
Target Considerations

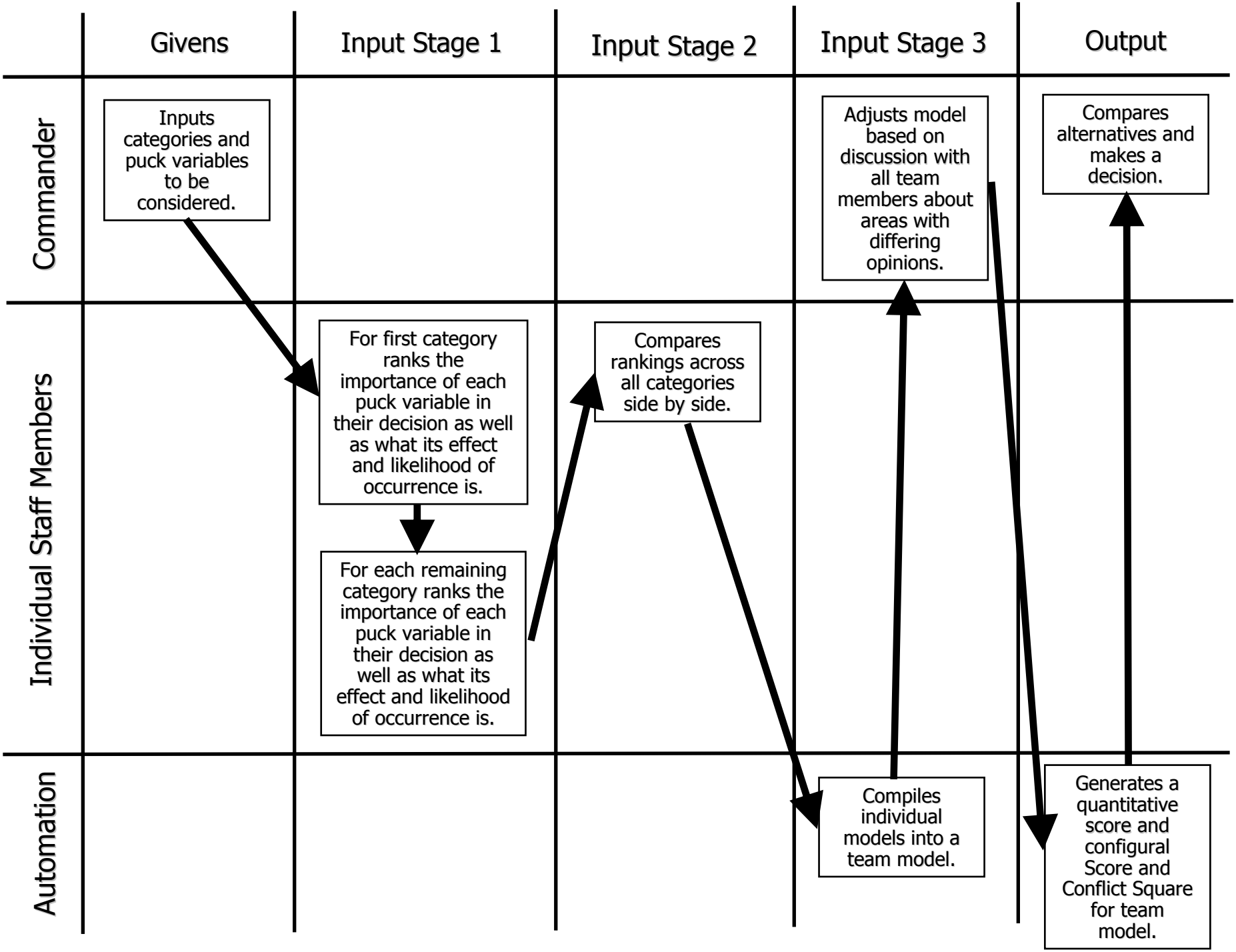



Givens
Input Stage 1
Input Stage 2
Input Stage 3
Output
Commander
Individual Staff Members
Automation
Inputs categories and puck variables to be considered.
For first category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
For each remaining category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
Compares rankings across all categories side by side.
Compiles individual models into a team model.
Adjusts model based on discussion with all team members about areas with differing opinions.
Compares alternatives and makes a decision.
Generates a quantitative score and configural Score and Conflict Square for team model.

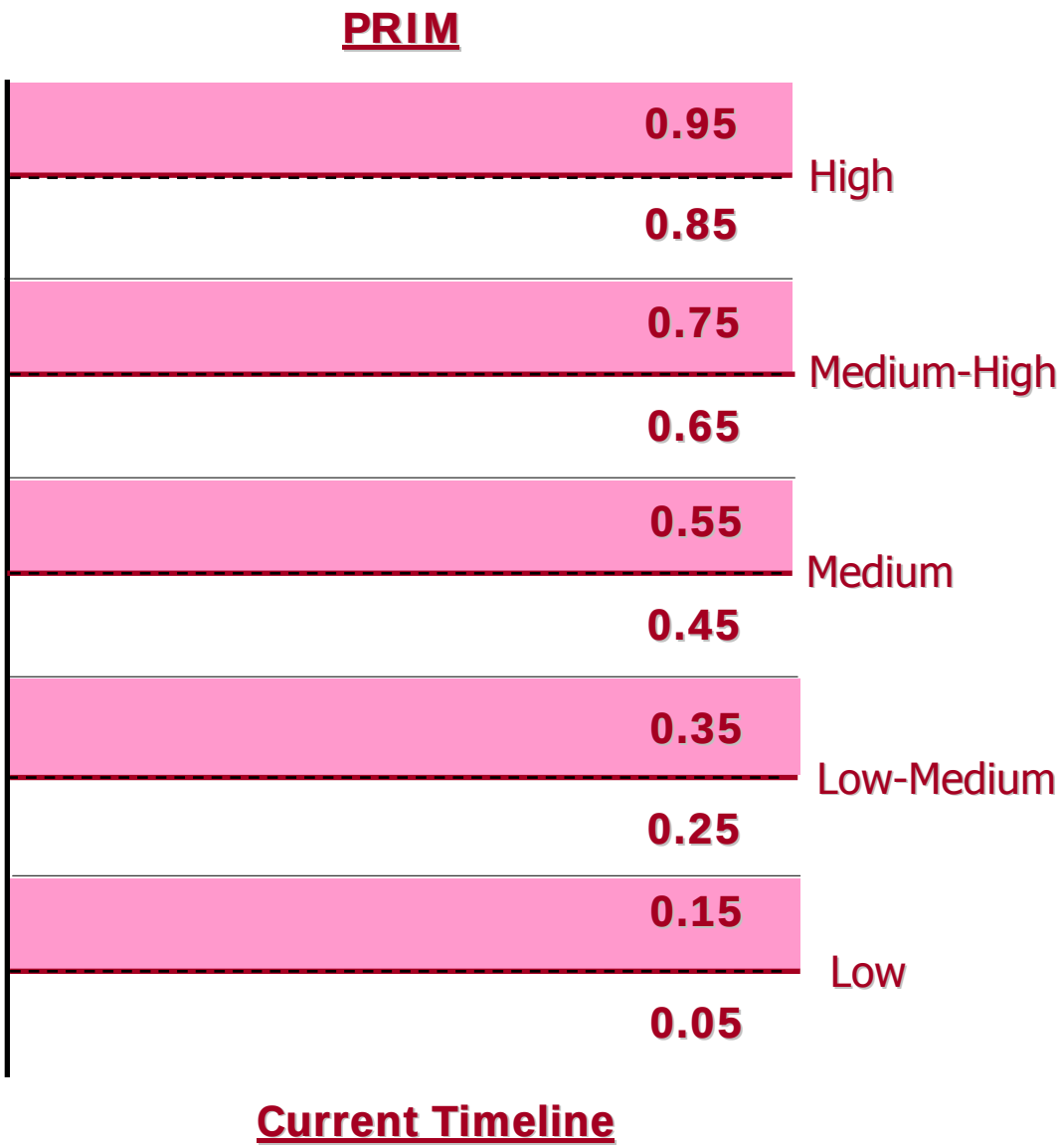

Crew
Aircraft/Munitions
Target
+ / -
Aircraft Fatigue
+ / -
Crew's Current Performance
+ / -
Crew's Rhythm of Ops Tempo
+ / -
Necessity of Quick Target Destruction
High
+ / -
Crew's Current Workload
+ / -
Munitions Performance in Weather
+ / -
Target Workload
+ / -
Target Performance
Medium-High
+ / -
Crew's Fatigue
+ / -
Aircraft Available
+ / -
Munitions Available
Medium
+ / -
Crew's Alertness
+ / -
Target Defenses
Low-Medium
+ / -
Crew's Cohesion
+ / -
Aircraft Performance in Weather
Low
Current Timeline

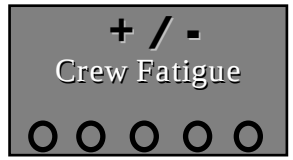

Givens
Input Stage 1
Input Stage 2
Input Stage 3
Output
Commander
Individual Staff Members
Automation
Inputs categories and puck variables to be considered.
For first category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
For each remaining category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
Compares rankings across all categories side by side.
Compiles individual models into a team model.
Adjusts model based on discussion with all team members about areas with differing opinions.
Compares alternatives and makes a decision.
Generates a quantitative score and configural Score and Conflict Square for team model.


Crew
Aircraft/Munitions
Target
+ / -
Aircraft Fatigue
+ / -
Crew's Current Performance
+ / -
Crew's Rhythm of Ops Tempo
+ / -
Necessity of Quick Target Destruction
High
+ / -
Crew's Current Workload
+ / -
Munitions Performance in Weather
+ / -
Target Workload
+ / -
Target Performance
Medium-High
+ / -
Crew's Fatigue
+ / -
Aircraft Available
+ / -
Munitions Available
Medium
+ / -
Crew's Alertness
+ / -
Target Defenses
Low-Medium
+ / -
Crew's Cohesion
+ / -
Aircraft Performance in Weather
Low
Current Timeline


Givens
Input Stage 1
Input Stage 2
Input Stage 3
Output
Commander
Individual Staff Members
Automation
Inputs categories and puck variables to be considered.
For first category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
For each remaining category ranks the importance of each puck variable in their decision as well as what its effect and likelihood of occurrence is.
Compares rankings across all categories side by side.
Compiles individual models into a team model.
Adjusts model based on discussion with all team members about areas with differing opinions.
Compares alternatives and makes a decision.
Generates a quantitative score and configural Score and Conflict Square for team model.

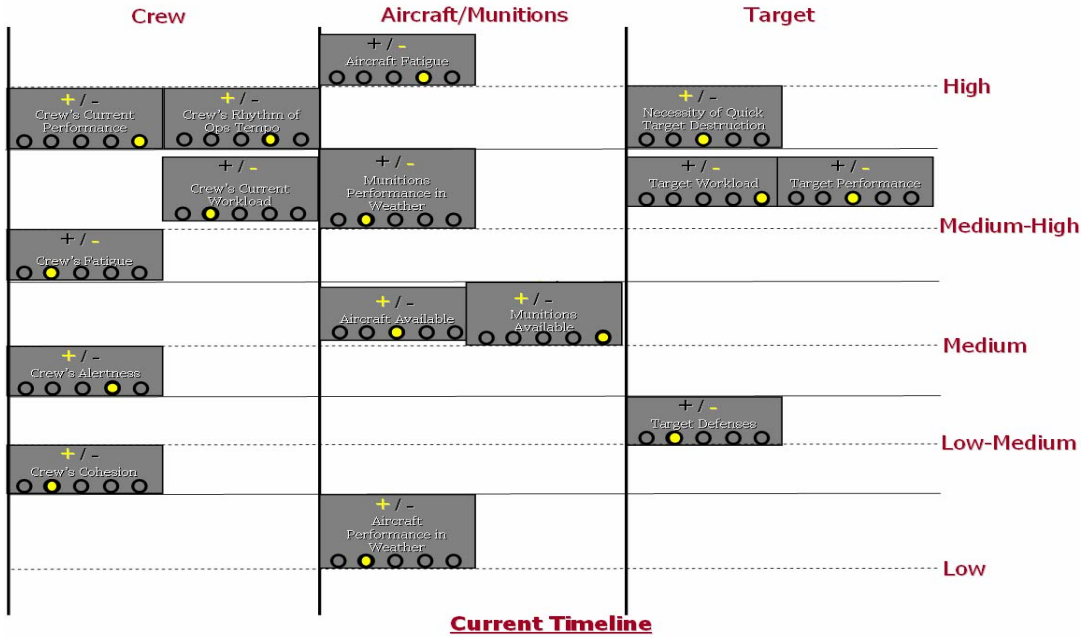
PRIM: Behind the Scenes





Very Unlikely:	0.05
Unlikely:	0.25
Neutral:	0.50
Likely:	0.75
Very Likely:	0.95

PRIM: Multi-Attribute Equation



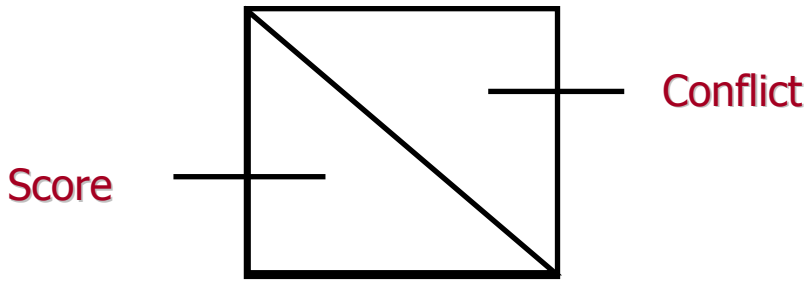
$$Score = C \bullet \sum_{i=1}^{j} [\, p(x_i)\text{^}1.5 \bullet U(x_i)]$$

- i is the puck peing considered at the time
- j is total number of different pucks for x_i through x_j.
- $p(x_i)$ is the likelihood (probability) rating of that puck's variable occurring
- $U(x_i)$ is the importance (utility) rating of the puck's variable in the decision.
- The $U(x_i)$ is positive or negative based on what is marked on the puck.
- Normalize by multiplying by C to put on a scale of -100 to 100.

PRIM Output

Option	Score
Current Timeline	9.788
Delay Timeline	4.830

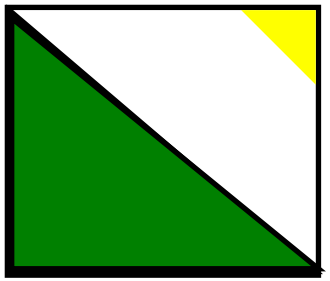
Score & Conflict Square (SCS)



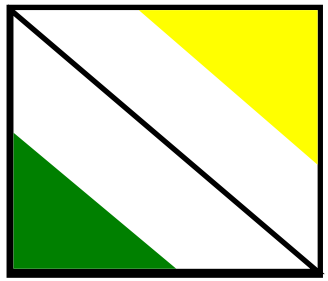
- The Score & Conflict Square (SCS)
  - Configural display of results
  - Comprised of two triangles
    - Score
    - Conflict

Support Conflict Square (SCS)

(a)

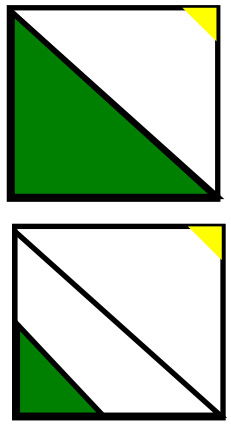


(b)



- Support
  - Fills with green triangle based on how high scoring the option is (the best choice is always completely full, as seen in a)
- Conflict
  - Fills with a yellow triangle based on how many of the variable characteristics (probability and utility) are in conflict for the option

PRIM Output



Option	Score
Current Timeline	9.788
Delay Timeline	4.830

General Benefits

- **PRIM is a possible design solution**
- **Technology may not generate a solution, but may facilitate dialogue toward a solution from qualified experts**
- **Focus discussion on critical differences**
- **Highlight key factors for decision**

Resources

1. Clemen, R.T. (1996). Making Hard Decision: An Introduction to Decision Analysis. Pacific Grove, CA, Duxbury Press at Brooks/Cole Publishing Company.
2. Gigerenzer, G., Todd, P. M., & Group, T. A. R. (1999). *Simple Heuristics That Make Us Smart*. Oxford, NY: Oxford University Press, Inc.
3. Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica,* 47(2), 263-292.
4. Klein, G. (1999). *Sources of Power: How People Make Decisions*. Cambridge, MA: The MIT Press.
5. Klein, G., Phillips, J. K., Rall, E. L., & Peluso, D. A. (2004). A Data/Frame Theory of Sensemaking.
6. Omodei, M. M., Wearing, A. J., McLennan, J., Elliott, G. C., & Clancy, J. M. (in press). *More is better? Problems of self-regulation in naturalistic decision making settings.* Mahwah, NJ: Lawrence Erlbaum Associates.
7. Oskamp, S. (1965). Overconfidence in case study judgments. *Journal of Consulting Psychology, 29*(261-265).
8. Sanders, M. S., & McCormick, E. J. (1993). *Human Factors In Engineering and Design*. New York: McGraw-Hill.
9. Shanteau, J. (1992). Competence in experts: The role of task characteristics. *Organizational Behavior and Human Decision Processes, 53*, 252-266.
10. Slovic, P., Fischhoff, B., & Lichtenstein, S. (1978). Behavioral decision theory. *Annual Review of Psychology, 28*, 1-39.
11. Wickens, C. D., Lee, J. D., Liu, Y., & Becker, S. E. G. (2004). *An Introduction To Human Factors Engineering* (Second ed.). Upper Saddle River, New Jersey: Pearson Education, Inc.
12. Wiener, E. L., & Nagel, D. C. (1988). *Human Factors In Aviation*. San Diego, CA: Academic Press.

Questions?

Hudson Graham, 2Lt, USAF

Graduate Student

Humans & Automation Lab

Massachusetts Institute of Technology

(617) 253-0993 || hgraham@MIT.edu