UR HITL C2 Proposed Metrics

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Factors to Consider

- Mission
- Battlespace state
- Available communication channels
- Data needs
- Security demands
- These factors define the required veracity, timeliness, truthfulness and data verification requirements
- Need for speed and complexity point to need for intelligent agent assistance and tools
  - Future work

Requirements as Baseline

- **Need to understand data volume requirement imposed**
  - **Let I_1 be the instantaneous data volume between any source and recipient**
  - **Then, total data volume need for an organization is defined as:**
    - $I_1 = \left(\prod_{j=1}^{n} I_{r_i} \leftarrow \prod_{j=1}^{m} I_{s_j} \right)$

Data Velocity and Data Traversal

- ω
- At a given time, T, the data velocity is defined as:
  - $(I_{1\tau} - I_{1\tau-1}) / I_{1\tau-1}$
- Data traversal is defined as I_2, which is
  - $I_2 = \left(\left(\prod_{i=1}^{n} I_{r_i} \leftarrow \prod_{j=1}^{m} I_{s_j}\right)\right) \div \sum\left(\Delta t(r_i \leftarrow s_j) \;\; \forall \;\; (r_i \leftarrow s_j) \neq 0\right)$
- I_2 must be minimized
  - No contention for bandwidth
  - Data moves promptly
- Must consider time required for priority data to arrive at its destination
  - Call this priority data *y*

Priority Data Considerations

- **I_{3p} is the average time for priority data to move all sources to all recipients of data of a given priority, *p***
  - **P_y is the set of priority data of a given priority in movement at any time**
  - **P_y, y=1,x is the set of all priorities for data**
  - **I_{3p} at time y is defined as:**

$$\left(\left(\prod_{i=1}^{n} I_{r_i} \leftarrow \prod_{j=1}^{m} I_{s_j}\right)\right) \div \sum\left(\Delta t\left(r_i \leftarrow s_j\right)\left[\ni\left(\left(r_i \leftarrow s_i\right) \neq 0 \wedge \left(r_i \leftarrow s_j\right) \subset p_y\right)\right]\right)$$

  - **Allowing I_3 to be defined as**

$$\sum_{y=1}^{x} I_{3p_y} \div x$$

Need Differential

- I_4 is defined as the difference between when the data is needed and when it arrives at a recipient
  - For a given time period
  - Must be minimized for each recipient and the organization
- I_4 for a recipient *r* is defined as:

$$\sum_{j=1}^{m}\left(t_{a_r}-t_{n_r}\right) \forall \left(I_r \leftarrow \prod_{j=1}^{m} I_{s_j} \ni \left(r_r \leftarrow s_j\right) \neq 0\right)$$

- For the organization, I_4 can then be defined as:

$$\sum_{r=1}^{n} \mathrm{I}_{4_r}$$

- I_3 for a recipient must be minimized in order to minimize I_4

Need Differential for Data of a Priority

- I_5 is defined as the time differential between when the dat of a given priority is needed by a recipient and when it arrives
- I_5 for a recipient is then defined as follows:

$$\sum_{j=1}^{m}\left(t_{a_r}-t_{n_r}\right)\forall\ I_r \leftarrow \prod_{j=1}^{m} I_{s_j}\ \ni \left(\left(\left(r_r \leftarrow s_j\right)\neq 0\right)\wedge\left(\left(r_i \leftarrow s_j\right)\subset p_y\right)\right)$$

- Should approach zero for data of highest priority for each data recipient

Data Movement Efficiency

- Ψ
- **Defined for each recipient at a given time**
- **Data efficiency is based on performance as measured by I_4**
- **Ψ for a given recipient for a given time is defined as:**
  - $\psi_{r\tau} = (I_{4r\tau} - I_{4r\tau-1}) / I_{4r\tau-1}$

Further Considerations on Data Transport

- **Data transport time, I_2, is based upon**
  - **Time spent in transit in a medium**
  - **Time spent in computing devices**
  - **Time spent in sensor systems**
  - **Time spent in releasibility decision making**
  - **Time spent in analysis**
- **Transit, computing, and sensor times are nearly constant**
- **Key is minimizing releasibility and analysis time**
  - **Argues for automation of these critical but sensitive tasks**
    - **Intelligent agents**
      - **For prioritization as well as information overload management**
  - **Same conclusions appear to hold for I_3, I_4, I_5**

Need an overall systems engineering approach, point solutions are <u>not</u> likely to be scalable or sufficient

Major Metrics Redux

Metric/ Variable	Definition
I_1	The volume of data moving from all sources of data to all recipients of data within an organization at any given time
I_2	The average time for data to move from all sources to all recipients within a time period
I_3	The average elapsed time for priority data of a given priority to move from all sources to all recipients of data of that priority at any given time.
I_4	The time differential between the time when data is needed by a recipient and when it is received.
I_5	The time differential between the time when data is needed by a recipient and when it received by the data recipient for a given time period for data of a given priority.
ϖ_τ	Data velocity within an organization at a time τ
ψ	The efficiency of the movement of data.

Future Work

- Extend metrics proposed here
  - Develop component representations
- Need real-time network instrumentation to enable management of network
  - Sensors, data needed, dissemination
- Need training to prepare for cyberattacks
- Need insight into systems engineering for NCO networks
  - Better end-to-end engineering to insure efficient, prioritized data transport
- Better insight into user needs for data
  - Proper prioritization