



Federated Conjunction Assessment: A Framework for Reconciling Multiple Risk Assessment Solutions



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Motivation

- Multiple ephemeris providers yield conflicting collision probability (P_c) estimates.
- Larger uncertainty on one solution may drive P_c over an action threshold.

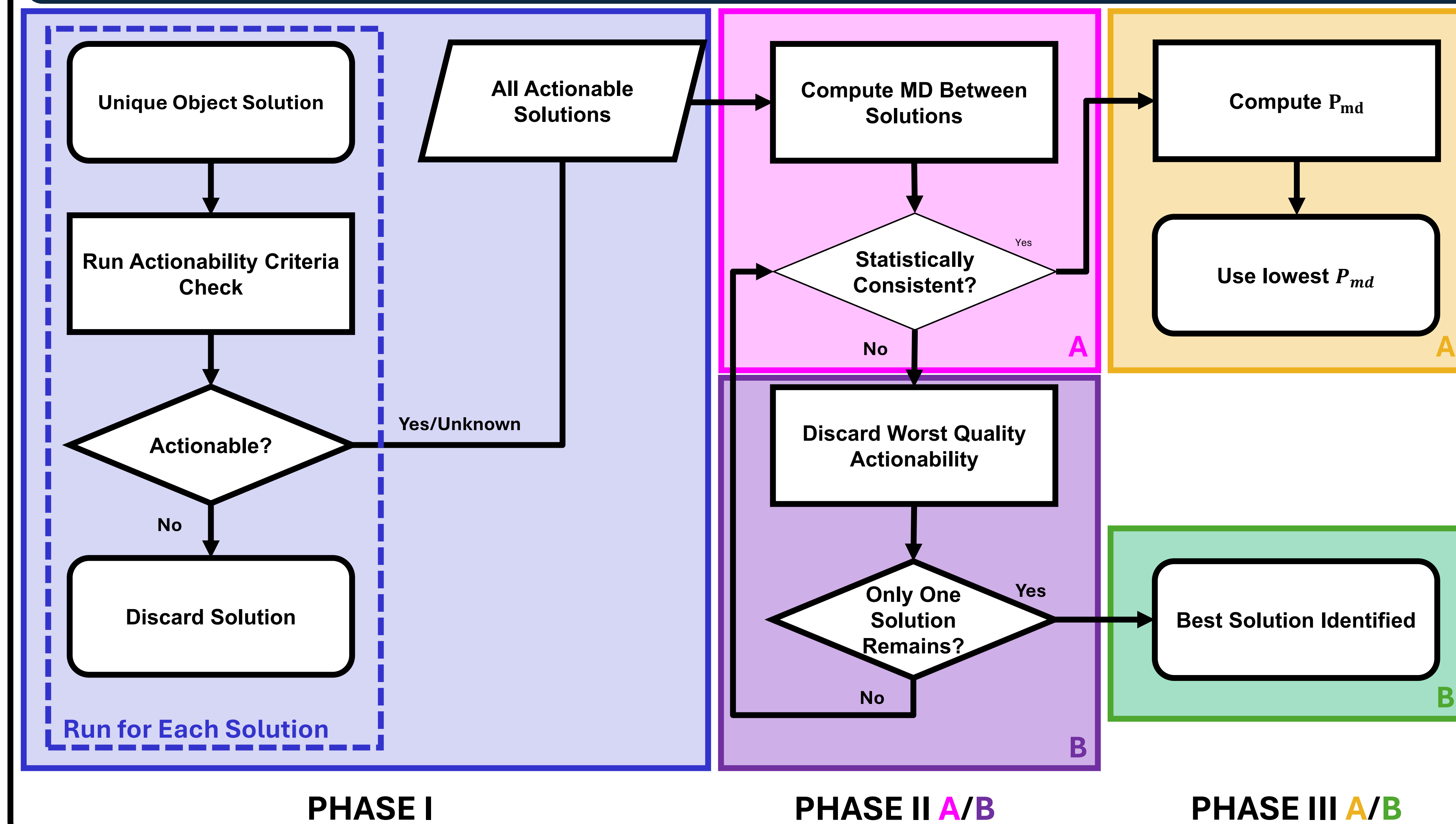
Objective

- Develop rigorous framework to evaluate, filter and reconcile multiple solutions for the same conjunction.

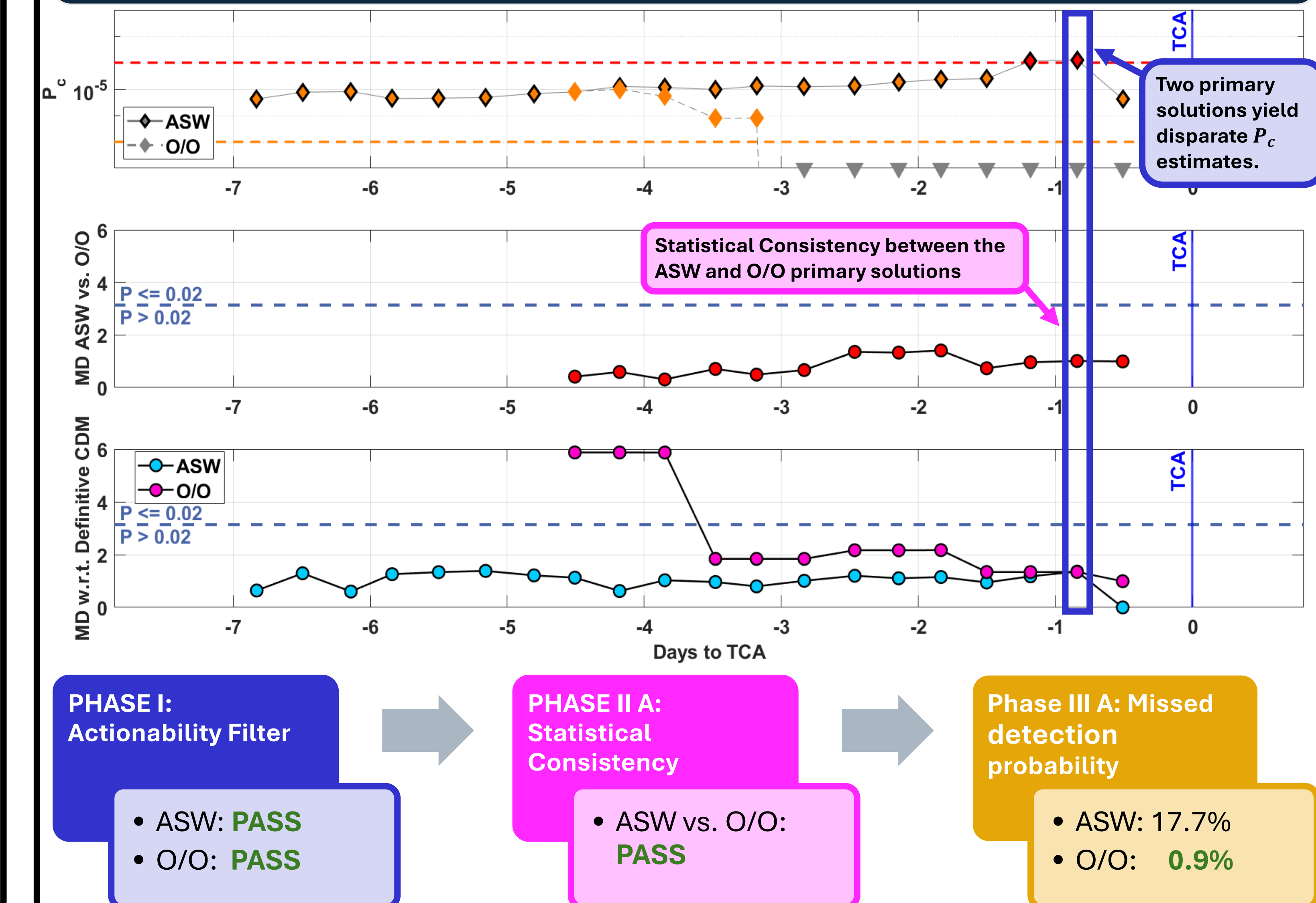
		PRIMARY		
		OWNER/ OPERATOR	18 SDS	Commercial SSA
SECONDARY	OWNER/ OPERATOR	1.85E-3	6.65E-5	No Pc
	18 SDS	7.18E-5	4.87E-6	No Pc
	Commercial SSA	No Pc	No Pc	3.16E-9

The N^2 challenge and conflicting risk assessments from multiple ephemeris providers.

Reconciliation Framework

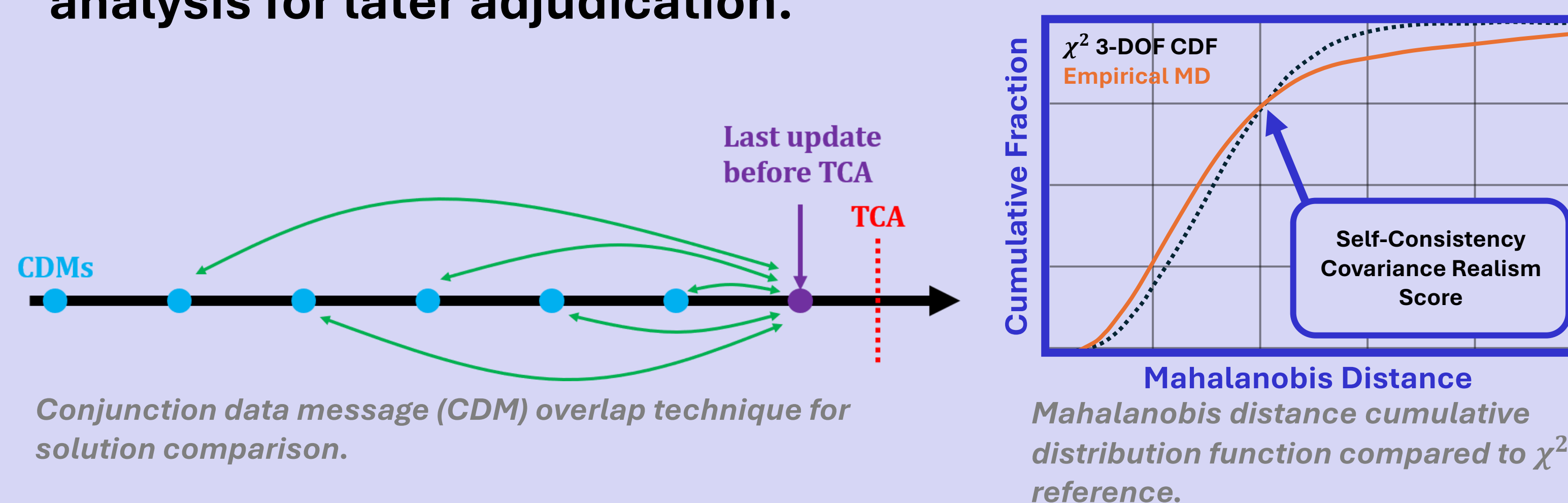


Case Study



PHASE I: Actionability Filter

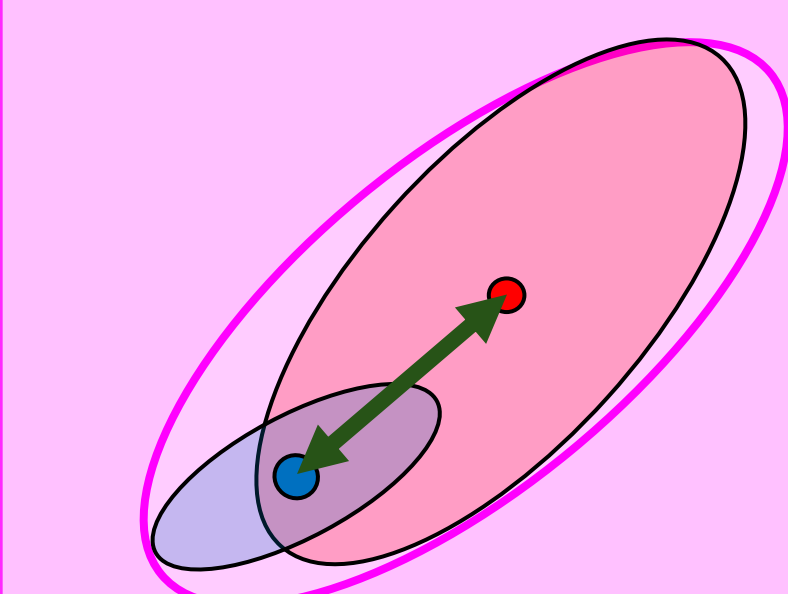
- Apply NASA CARA actionability criteria to each unique ephemeris solution [1].
- Discard solutions with clear quality issues.
- Attach OD quality scores derived from covariance realism analysis for later adjudication.



[1] NASA Office of the Chief Engineer, "NASA Spacecraft Conjunction Assessment and Collision Avoidance," 2023.

PHASE II A: Statistical Consistency Test

- Compute 3 degree-of-freedom (DOF) Mahalanobis distance (MD) between actionable solutions relative to combined covariance.
- Compute P-values with the χ^2 distribution with 3-DOF.



Primary State Estimates

P-value < 0.02
Statistically Inconsistent
Proceed to Phase II B

P-value ≥ 0.02
Statistically Consistent
Proceed to Phase III A

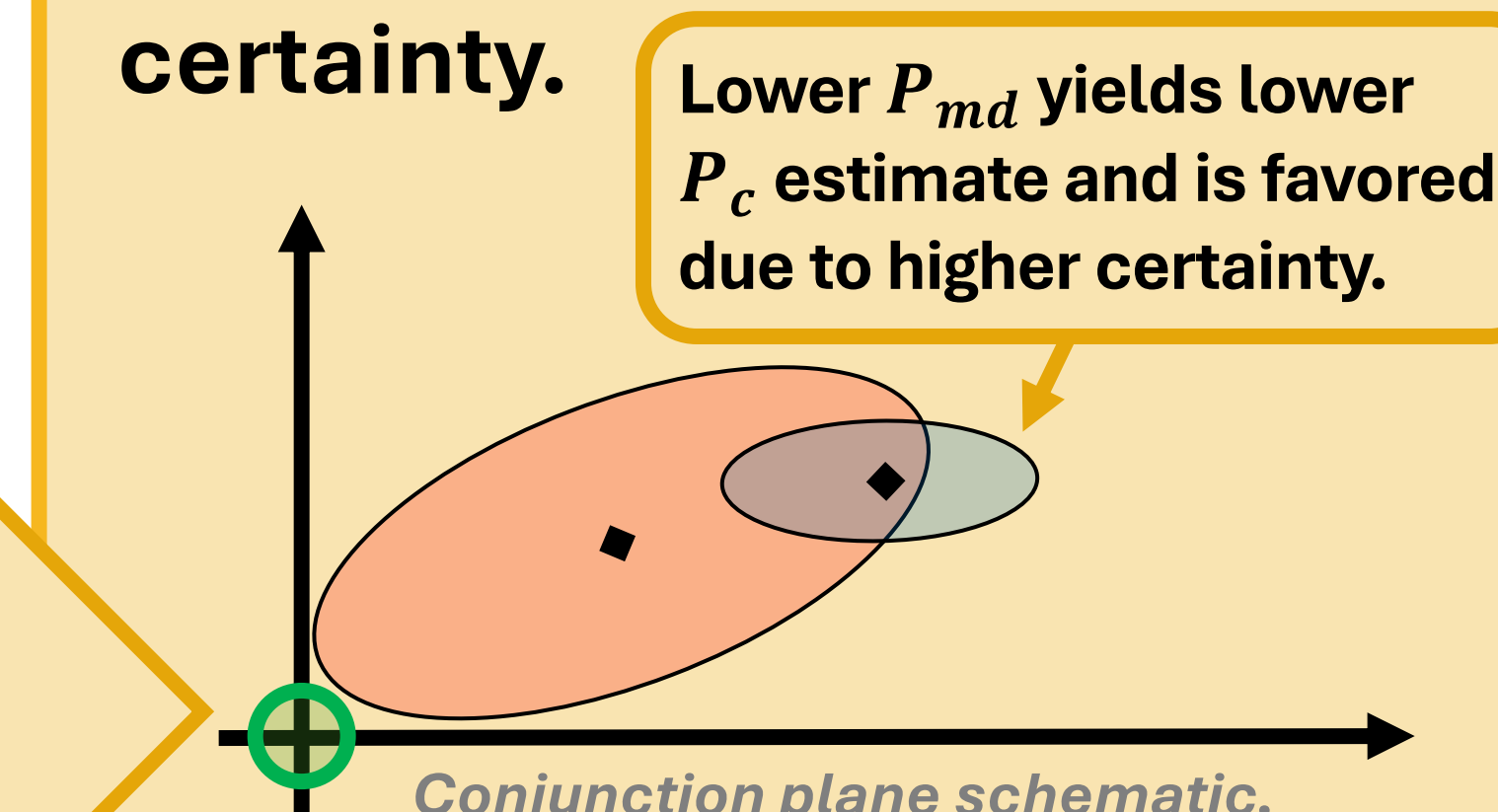
PHASE II B: Iterative Pruning

- Engaged when multiple, statistically inconsistent solutions persist.
- Discard the solution with the lowest score from Phase II A and return to Phase II A until statistical consistency achieved or only one solution remains.

Best solution identified if only one solution remains.

PHASE III A: Adjudication by P_{md} [2]

- Evaluate the direct-hit missed detection probability (P_{md}).
- Prefer the lowest P_{md} (i.e., the smallest conjunction-plane covariance and highest certainty).



[2] T. Sweetser, B. Braun, M. Acocella and M. Vincent, "Quantitative assessment of a threshold for risk mitigation action," *Journal of Space Safety Engineering*, vol. 7, no. 3, pp. 318-324, 2020.

Conclusions

- **Proven Results:** Retrospective analysis shows the framework directs operators to the best risk assessment solution.
- **Operational Blueprint:** Currently used with human oversight at CARA, serves as a foundation for future automated decision-making in a federated SSA ecosystem.
- **Future Work:** Further research will explore state and covariance fusion and methods to generate synthetic CDMs.