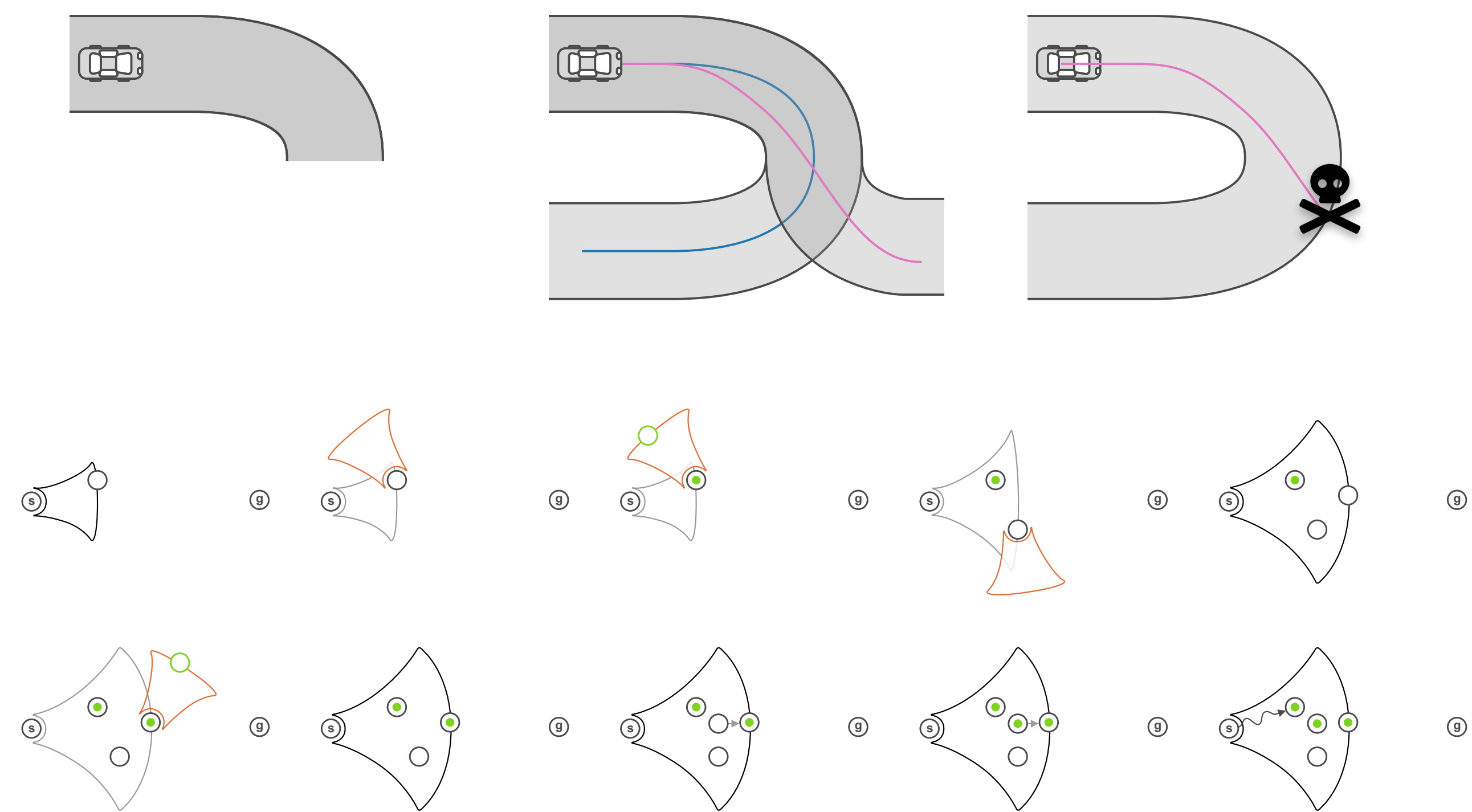


Improved Safe Real-time Heuristic Search

Bence Cserna, Kevin C. Gall, Wheeler Ruml

Prior Work

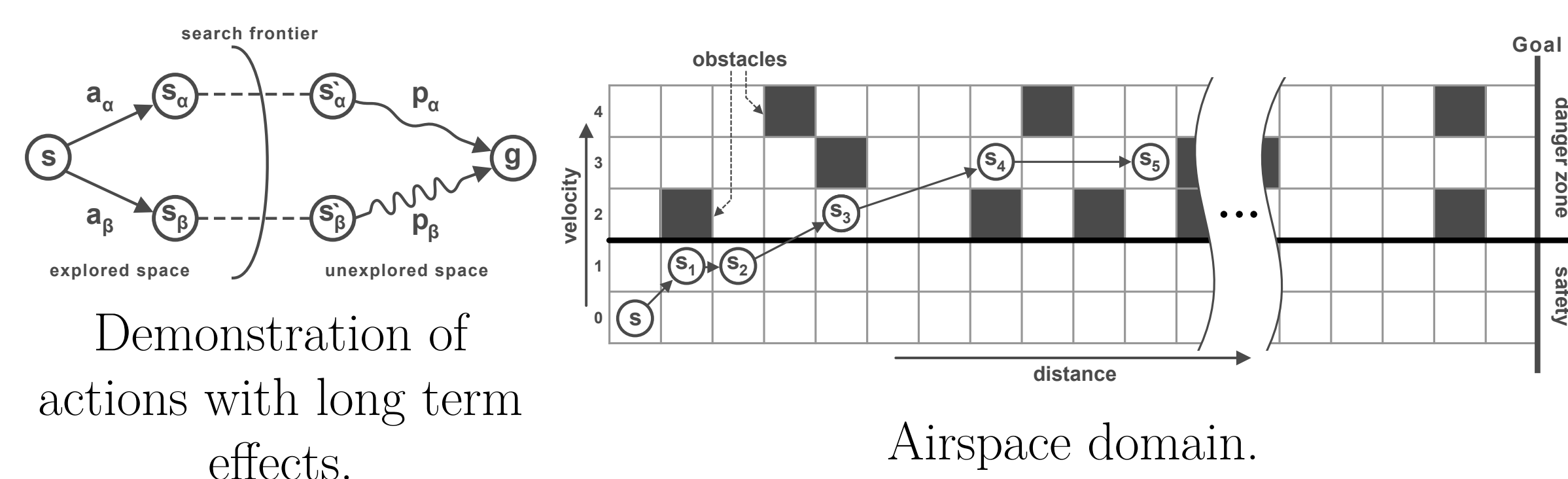
Safe Real-time Search (SafeRTS, AAAI-18) addresses real-time environments with dead-end states.



Contributions

- A new experimental domain to evaluate safe real-time planning methods.
- An analysis of the deficiencies of Safe Real-time Search.
- A general framework for safe real-time planning that addresses these drawbacks.
- A dead-end propagation to reduce the number of re-expansions.

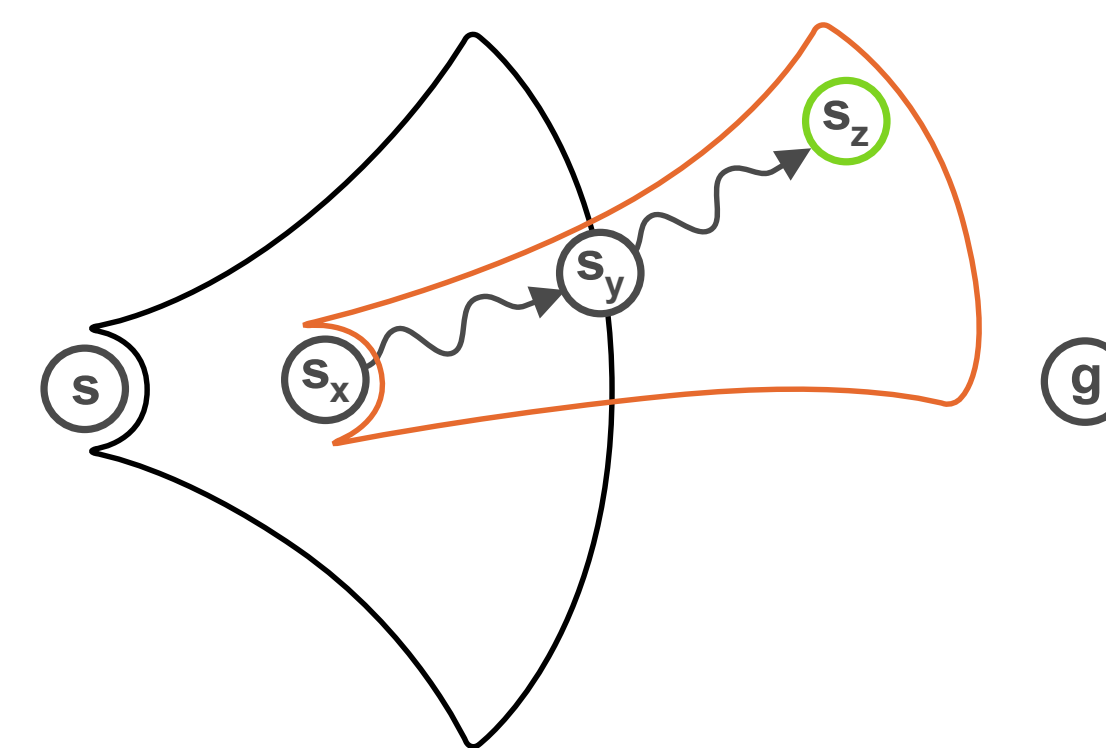
Airspace Domain



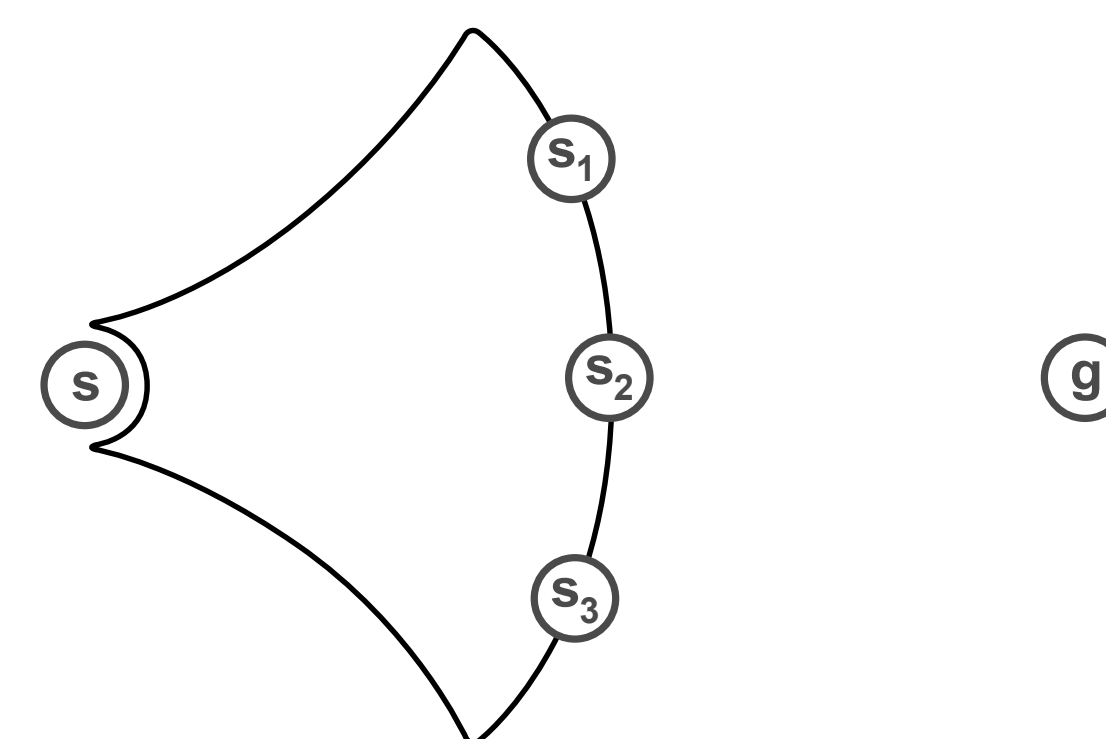
altitude	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
safety probability	.95	.94	.89	.88	.86	.80	.74	.70	.64	.58	.51	.43	.35	.27	.19	.12	.06
proof length	4	5	6	8	9	11	12	14	16	18	20	23	25	27	29	31	32
successful proof expansions	4	5	7	8	10	12	14	18	21	26	32	38	45	53	60	65	68
failed proof expansions	1	1	1	1	2	2	2	3	4	5	8	10	13	14	14	11	7

Real-time Framework for Safety

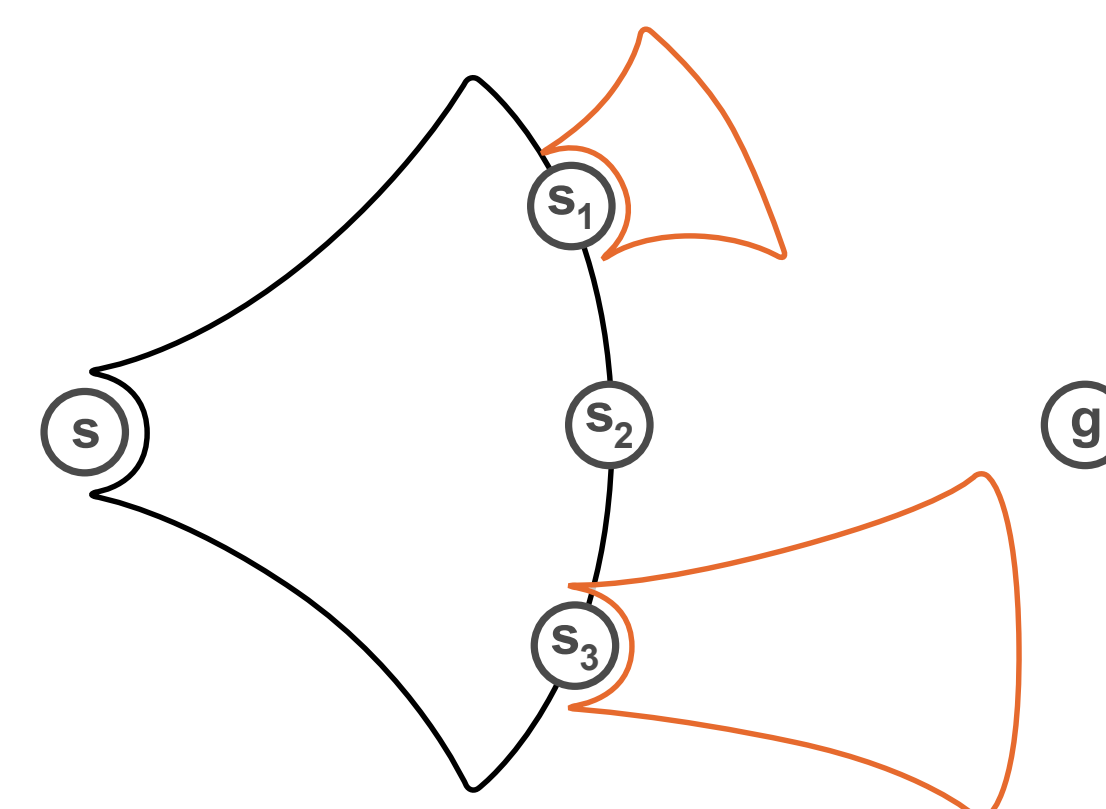
Proving the safety of a state is inherently more expensive when the local search space is immature.



RTFS exploits the real-time search bound to reduce redundant work within search iterations. It first expands all local states before it attempts to prove their safety.

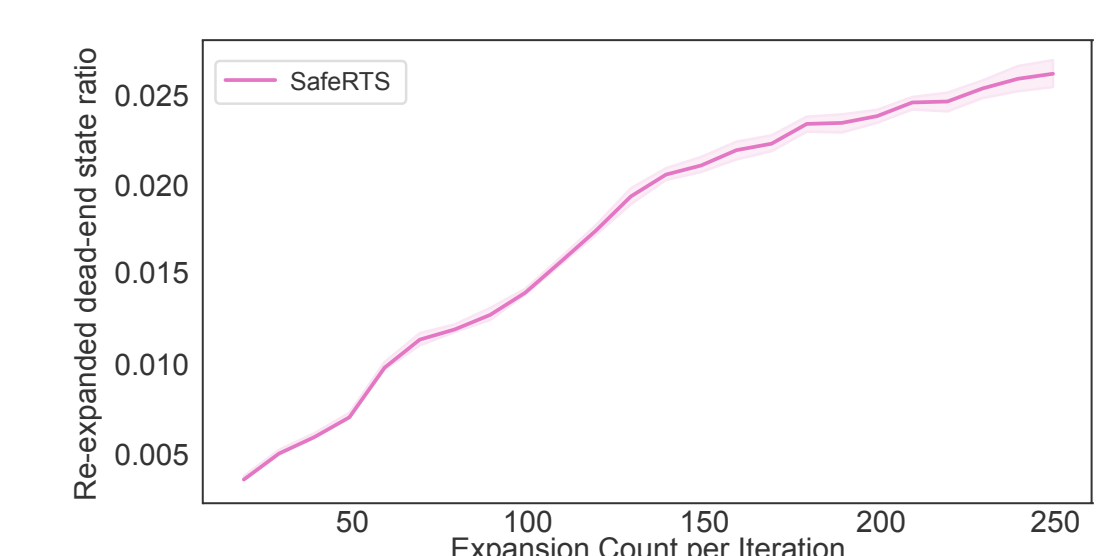


After the expansion phase RTFS can make a more informed decision on which states should be proven to be safe.



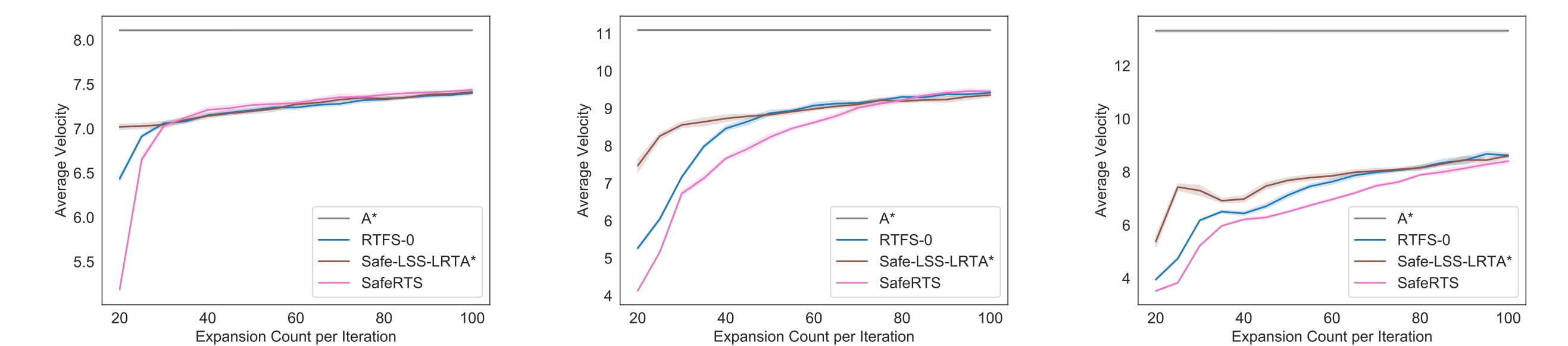
Propagation of Dead-ends

Using information gathered about dead-ends during safety proofs can reduce future planning effort.

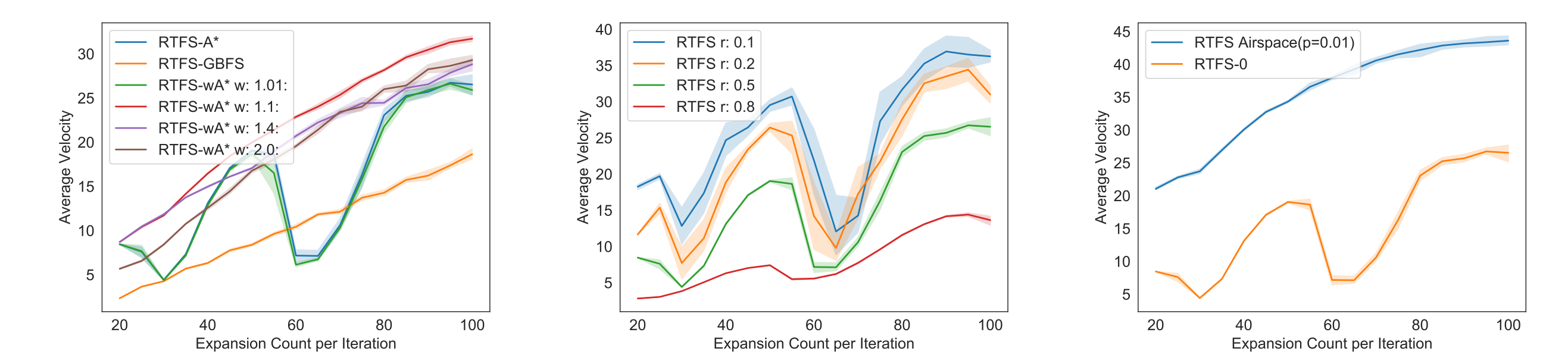


Ratio between dead-end re-expansions and total number of node expansions.

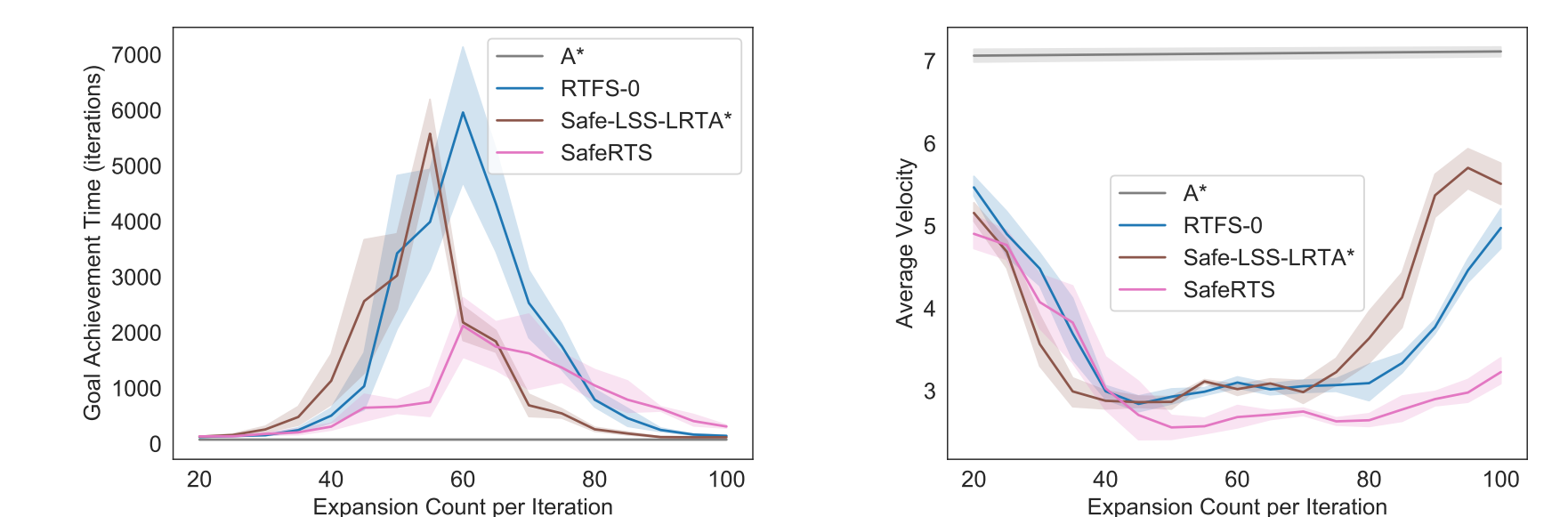
Empirical Validation



Average velocity on the Airspace domain of length 100,000 with altitude limits of 10, 14, and 20.



Difficulty of safety proofs in the Airspace domain ($p_{obs} = 0.05$) averaged over 100,000 states per altitude



GAT on the Hansen-Barto racetrack. Average velocities on the Hansen-Barto racetrack.

Undesirable phenomena in the racetrack domain.

Conclusion

- First we introduced a new domain with dead-ends called Airspace that minimizes the long term effects of actions.
- Second, we showed that the simple method of caching dead-ends provided a mild performance improvement.
- Third, we proved that proving safety is more effective when it is done after expanding the local state space.
- Lastly, we combined these findings into a flexible planning framework, RTFS, to address real-time planning in the presence of dead-ends.