National Aeronautics and Space Administration

MOSAIC: Mars On-site Shared Analytics Information and Computing

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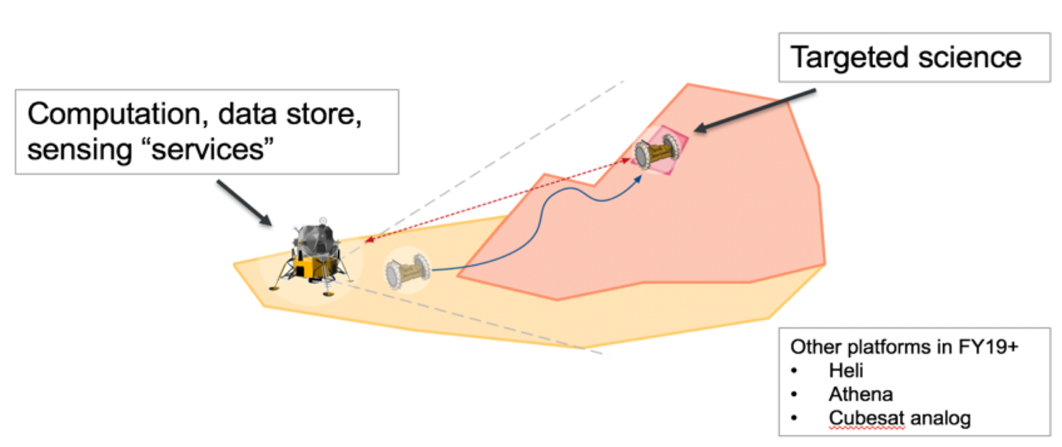
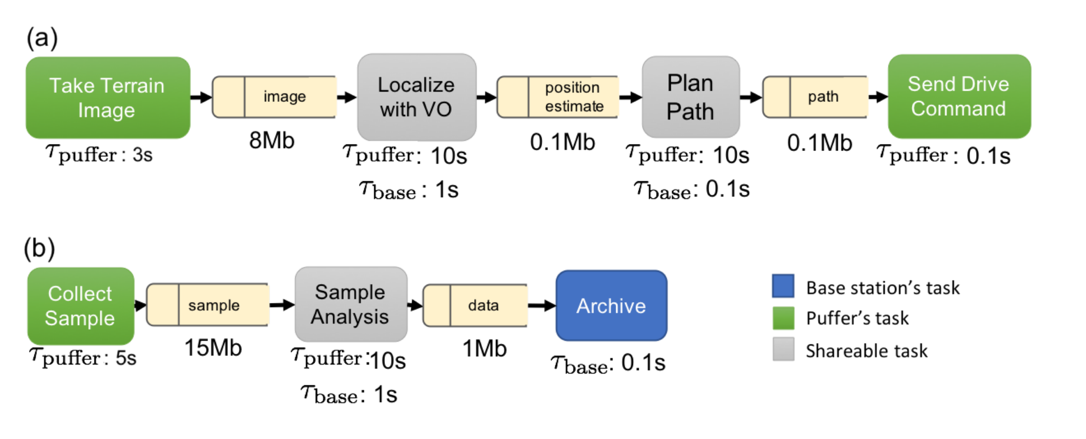
Optimal distributed scheduling of computation and communication for multi-agent systems

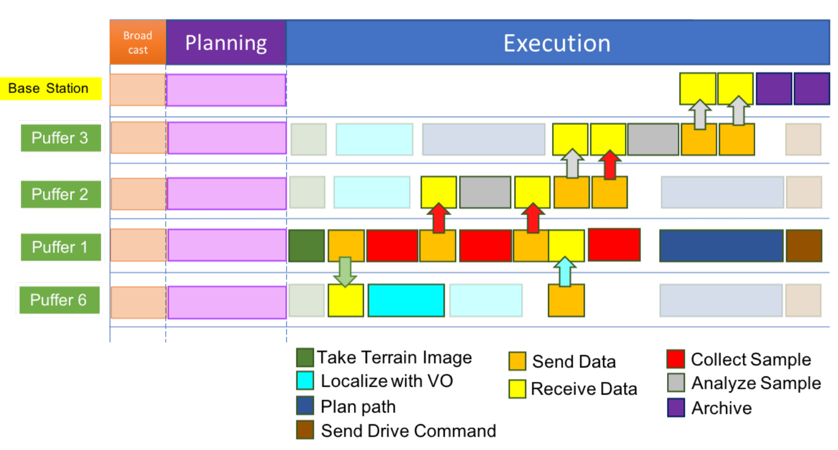
See our results at: github.com/nasa/MOSAIC

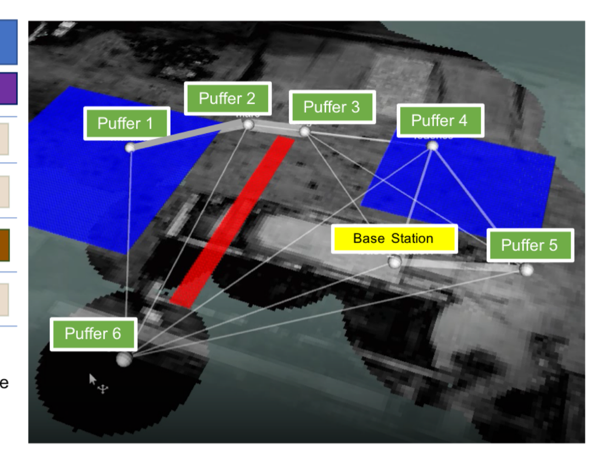


1) **Concept of operations.** Left: The base station has more computational resources than any PUFFER, but the PUFFER can enter high-risk areas carrying small sensors to gather samples. Fig 4 (below): An *orbiting* server could accommodate many systems.



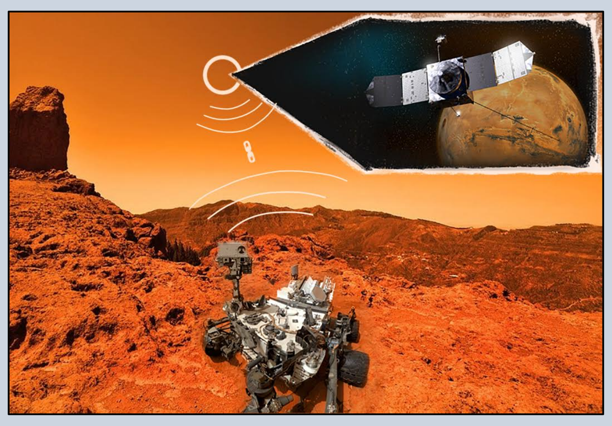
2) **The key problem is scheduling** of tasks with dependencies (above) onto the timeline of available compute nodes (see 3) subject to coms. We present in [1] an anytime scheduler for this distributed task allocation and scheduling problem.



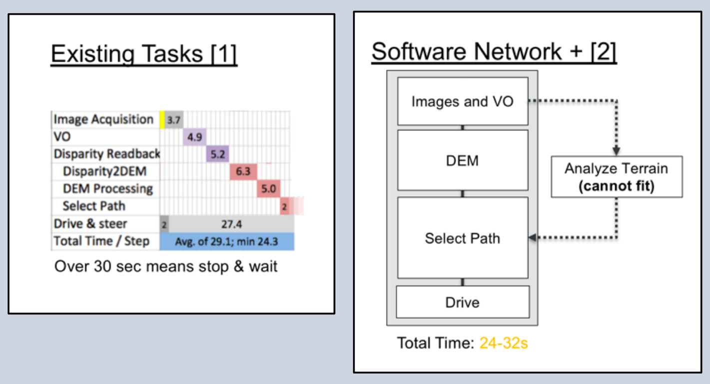


3) **Field tests conducted in 2018-2019** show a multi-agent system used "Assembly line" behavior, distributing tasks along communication chains to efficiently improve autonomy / science processing and data management. The system could gather and archive 2-3x more data w/ location-aware scheduling

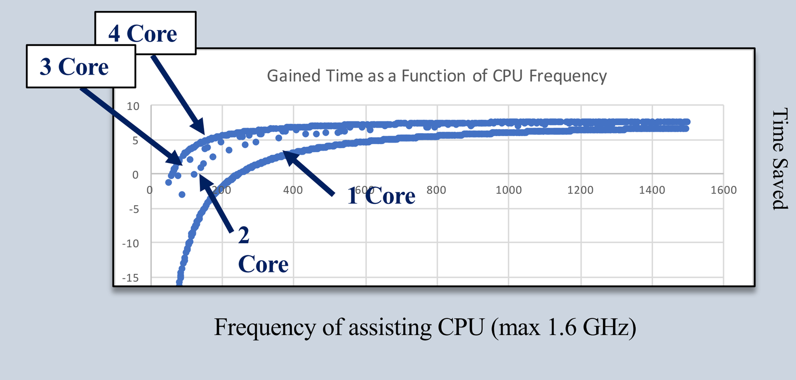
4) By leveraging a CPU assist, baseline Mars 2020 could transit Jezero crater up to 20% faster



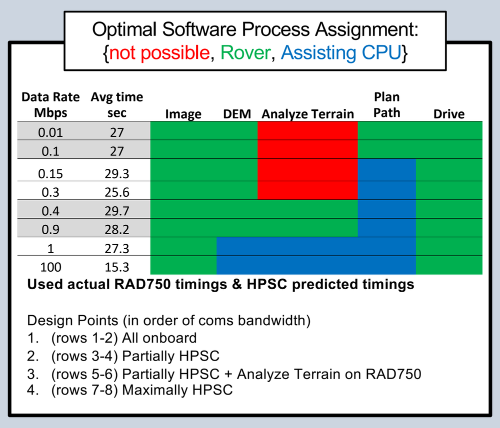
a) Illustration of possible mission



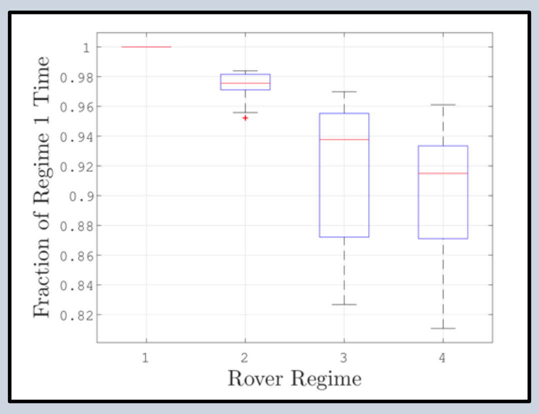
b) Decomposition of Tasks for Mars 2020 using real hardware profiling



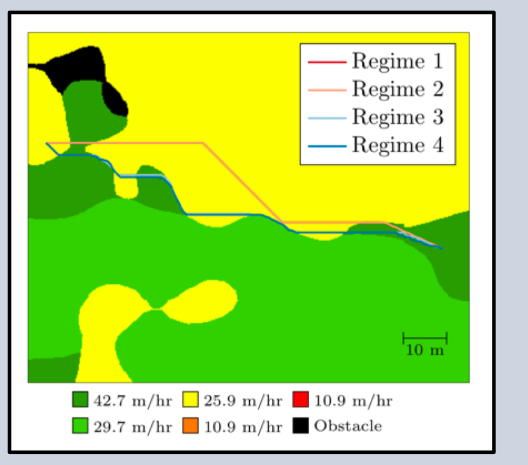
c) Savings in Mars 2020 planning time (seconds) as a function of CPU speed



d) tasks assigned to agents, as a function of bandwidth

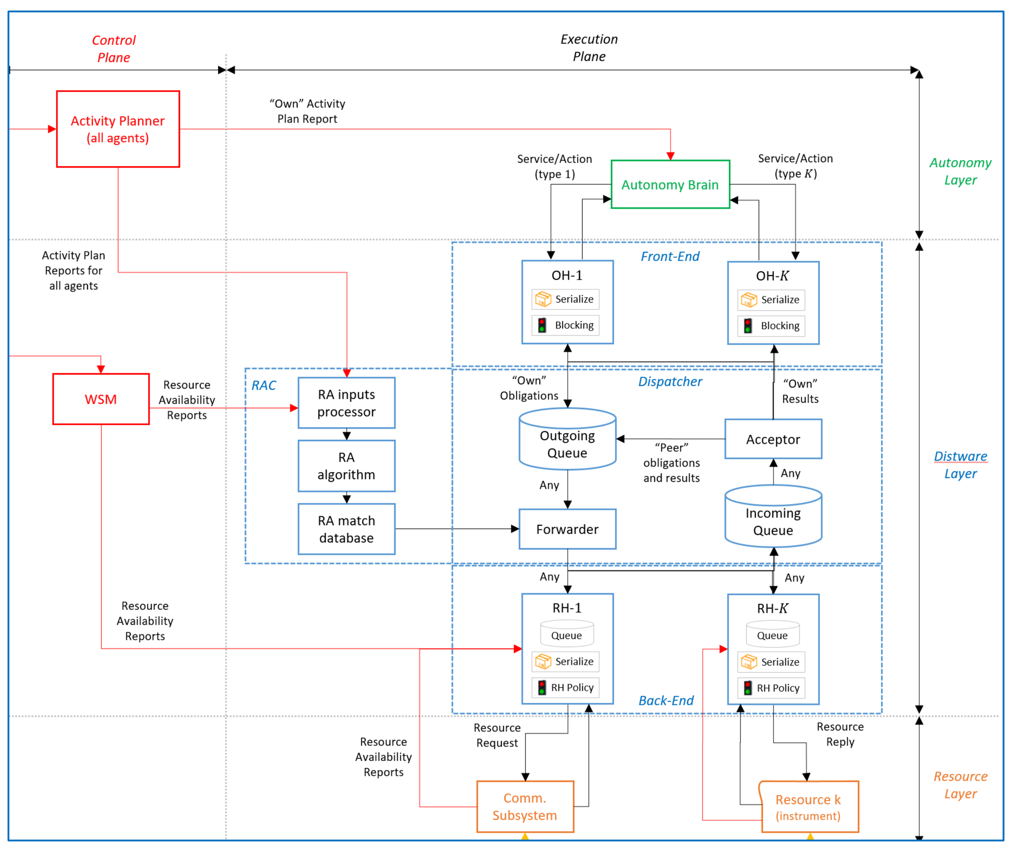


e) Resulting drive time for the assignments from (d)



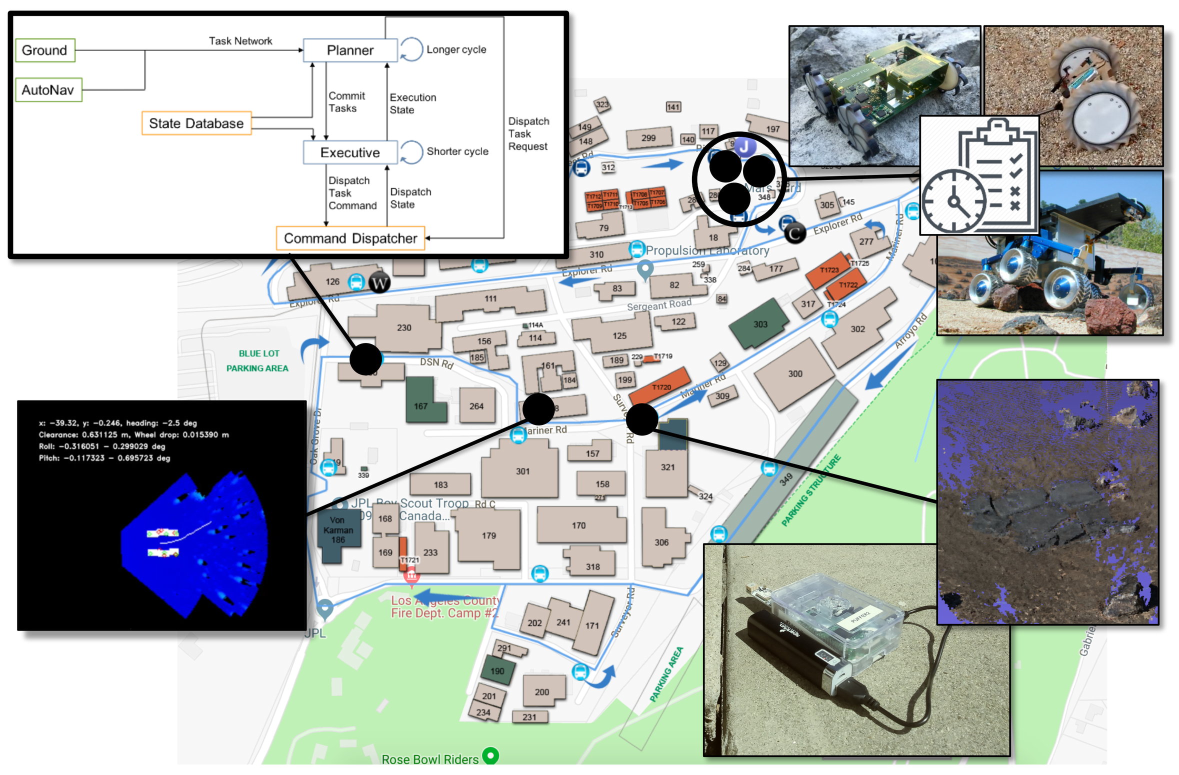
f) Resulting one-sol drive paths for the four assignments in (d)

ROS, AWS, DTN, and f-prime integration



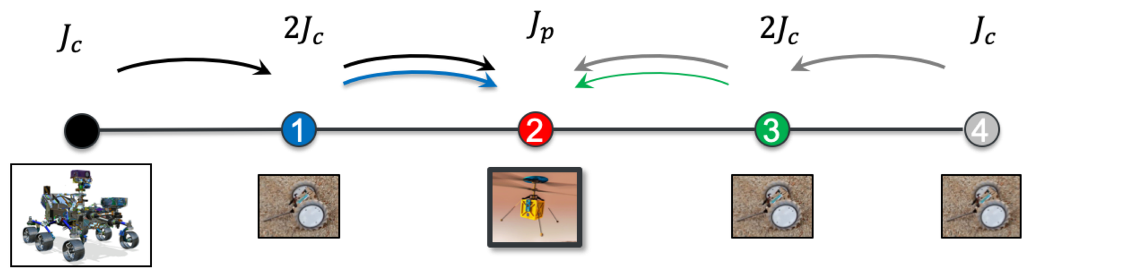
5) Our software framework integrates with ROS, or can be used standalone for distributed scheduling to link robots, AWS, or any other processing nodes.

We're building a distributed system across JPL

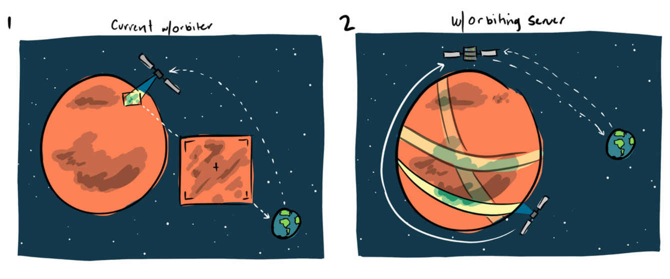


6) We are working towards a distributed system spanning the lab which allows autonomous robots to utilize coms architectures and compute resources made available for shared use. We have raspberry PI and docker images available for testing *right now.*

Infusion Paths and Next Steps



Planner	Hops	Max dv	Proc	Energy Cost	Factor	Notes
All	$n(n-1)$	n	n	$n \cdot J_p + J_c(n^2 - n)$	N/A	Edges leach
Base Station	$\frac{n}{2}(n-1)$	n	1	$J_p + J_c(n^2 - n)/2$	$\frac{1}{2}$	Big Improvement! Strains 1
Optimal: 2	$\frac{n}{4}(\frac{n}{2}-1)$	$\frac{n-1}{2}$	1	$J_p + J_c\left(\frac{n^2}{8} - \frac{n}{2}\right)$	$\frac{1}{4}$	Optimal *and* even Best if $J_p \approx 2\,J_c$



7) Our next steps involve a) more multi-robot research with PUFFER (See their poster!) and b) (lower) Studying a mars utility orbiter for supporting multiple systems (see Nebulae Poster, sponsored by the Keck Institute for Space Studies),

MOSAIC

NTRs to date

1. 51000 Cloud-based scheduler for mission studies and distributed systems research
2. 50997 ROS Service Manager
3. 51105 Pluggable Distributed Resource Allocator
4. 51131 Distributed (Multi-asset) Consensus-of-Information for Feature Tracking

Publications

1. Joshua Vander Hook, Tiago Vaquero, Federico Rossi, Marc Sanchez-net, Martina Troesch, Jean-Pierre de la Croix, Joshua Schoolcraft, Steve Chien. "Mars On Site Shared Analytics Information and Computing." International Conference on Planning and Scheduling (ICAPS)) 2019, Berkeley, CA.
2. Joshua Vander Hook, Tiago Vaquero, Martina Troesch, Jean-Pierre de la Croix, Joshua Schoolcraft, Saptarshi Bandyopadhyay, Steve Chien. "Dynamic Shared Computing Resources for Multi-Robot Mars Exploration" International Conference on Planning and Scheduling Workshop on Planning in Robotics (ICAPS-PlanRob) 2018, Delft, Netherlands.
3. Joshua Vander Hook, Tiago Vaquero, Martina Troesch, Jean-Pierre de la Croix, Joshua Schoolcraft, Saptarshi Bandyopadhyay, Steve Chien. "Dynamic Shared Computing Resources for Multi-Robot Mars Exploration" The International Symposium on Artificial Intelligence, Robotics and Automation in Space (i-SAIRAS 2018) Madrid, Spain.
4. Vaquero, T.; Vander Hook, J.; Troesch, M.; and Chien, S. A Simulation Framework for Computation Sharing in Mars Spacecraft Network. In International Conference on Planning and Scheduling (ICAPS 2018) System Demonstrations and Exhibits Track, Delft, Netherlands, June 2018.

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ACKNOWLEDGEMENTS: This work was originally supported by Office of Naval Research. This work is concurrent with two 6X-directed tasks and a Keck Institute for Space Studies workshop. Demonstrations are joint with 9X under their *Constellations* Strategic Initiative.