A recent published paper:

"Enabling Exploration Missions Now: Applications of On-Orbit Staging," American Astronautical Society Paper AAS 05-273, by David C. Folta, Frank J.Vaughn, Jr., Paul A.Westmeyer, Gary S. Rawitscher, and Francesco Bordi

describes a concept called "on-orbit staging" (OOS) that the authors believe is critical to achieving the objectives of the human exploration initiative. The authors say: "We demonstrate with multiple cases of a fast (< 245-day) round-trip to Mars, that using OOS combined with pre-positioned propulsive elements and supplies sent via fuel-optimal trajectories can reduce the propulsive mass required for the journey by an order-of-magnitude." The authors thereby imply strongly that such short round trip missions to Mars can be made viable.

The basis for the claims made in this paper is well known. The more demanding a propulsion operation is, the more it benefits from staging the propulsion system into segments such that the amount of propellant used to accelerate propulsion stages (as opposed to payload) is minimized.

For moderately demanding propulsion steps, staging provides moderate benefits. For example, consider the case representing trans-Mars injection from Earth orbit, where the change in velocity ($\Delta v$) is 4000 m/s, the specific impulse of the LH2-LOX propulsion system is 460 s, and the ratio of stage mass to propellant mass is 0.1. These correspond to a typical long-stay Mars mission. If the total initial mass in LEO (sum of payload, stage and propellant) is 1 mT, a single stage propulsion system can send a payload of 0.3375 mT on its way toward Mars. If this propulsion system is staged, the payload that it can send toward Mars is:

| | Payload/Initial mass |
|---|---|
| 1 stage | 0.3375 |
| 2 stage | 0.3539 |
| 3 stage | 0.3581 |
| 4 stage | 0.3600 |

The gains from staging are minor.

If we consider a round trip of a payload from LEO to the Mars surface and return to trans-Earth injection, using LOX-LH2 propulsion for Earth departure and CH4-LOX thereafter, with propulsion used for all steps, the values of $\Delta v$ for a long stay (500-600 days at Mars) mission are:

| Step | $\Delta v$ (m/s) |
|---|---|
| Earth departure | 4000 |
| Mars orbit insertion | 2500 |
| Mars descent | 4000 |
| Mars ascent | 4300 |
| Mars departure | 2400 |

With these values, the effect of using staging for all steps is summarized below:

| | Round Trip Payload/Initial mass in LEO |
|---|---|
| 1 stage | 0.0097 |
| 2 stage | 0.0116 |
| 3 stage | 0.0122 |
| 4 stage | 0.0124 |

Staging provides moderate benefits. However, staging beyond 2 stages produces diminishing returns.

Next, consider a short stay mission with its much higher values of Δv. For a 15-June (2020) 7-day stay mission, the Δv values given in the referenced paper are:

| Step | Δv (m/s) |
|---|---|
| Earth departure | 8320 |
| Mars orbit insertion | 8900 |
| Mars descent | 4000 |
| Mars ascent | 4300 |
| Mars departure | 9900 |

With these higher values of Δv, staging has a greater effect. For the round trip mission, we find that the mission cannot even be implemented with a single stage. Multiple stages are necessary or the rocket equation "blows up." The results are:

| | Round Trip Payload/Initial mass in LEO |
|---|---|
| 1 stage | Cannot be done |
| 2 stage | 0.0000647 |
| 3 stage | 0.0000893 |
| 4 stage | 0.0001010 |

Two things should be noted:

- Staging has a much greater effect in this case. Even the 4th stage produces a significant improvement in payload mass.

- The absolute values of payload mass are far inferior to the payload masses for a long stay mission. Even with 4 stages of propulsion, the payload mass is about 1% of that for a long stay mission.

- Even allowing for the fact that the short stay mission requires far less in the way of resources, and therefore the initial mass is lower by perhaps a factor of two, the short stay mission requires 50 times as many launches as the long stay mission.

Thus, with or without staging, the short stay mission is infeasible and unaffordable.

The best way that I can describe this paper is by an analogy.

Suppose an incredibly grossly overweight person weighing 1200 lbs discovered a new innovative diet. By following this innovative diet, he can reduce his weight by 30% to 840 lbs. He is very proud that he can produce such a large percentage weight reduction since a mildly overweight person weighing say, 200 lbs, could only expect to reduce his weight by say 10% to 180 lbs. Now the first person would be pleased with his performance on a percentage basis, and well he should. He could brag to the smaller person about his percentage gains. However, even after completion of his diet, he has a bloated weight that is neither conducive to health nor good looks. The smaller person, while undergoing a much smaller percentage reduction in weight, has an absolute weight that is much more conducive to health and looks.