Modular Saturn: The MLV INT-17, INT-18, and INT-19 Saturn II (Revised Ed)

So this quick document is based primarily on a work that @cobaltwolf found and linked to me recently knowing my love of the Saturn II concept.

Sandford, J., & Fraser, G. (1967). Adaptation of the Saturn S-II for Ground-Launch Stage. *SAE Transactions*, *75*, 841-854. Retrieved March 17, 2021, from http://www.jstor.org/stable/44564891

Look ma! I cited a document correctly :D

http://www.astronautix.com/data/satvint.pdf

then I didn't.

Beyond this document most of my research is on places like Wikipedia and Astronautix. Or to a historian a 3rd tier "public" source. That means they are at best stinking un-reliable if you were un-aware.

It should be noted that the primary source above PREDATES the final MLV studies which the INT-x numbers come from and there are snippets of Saturn II information throughout several of the NASA held MLV documents. Therefor while a reduced expansion bell for a "Surface Ignited J-2" is mentioned in this study, no details are provided. Neither are details on the 7 J-2 powered version or the "HG-3" powered versions. After the initial writing of this document, it was pointed out that the HG-3 was just a paper study engine and meant as a "Placeholder" for future technology. Two engines were in development at this time that fit the general size and performance envelope of the purported HG-3. The Pratt and Whitney Rocket division RL-20 and the XLR-129 which is derived from the RL-20.

The concept:

There is a significant mass to orbit gap between the Saturn IB as built and the Saturn V. While other proposals have looked at updating the Saturn IB (See MLV INT-12, -14, and -15 for examples,) no real work on such an upgrade was considered as the S-IB stage is over heavy and requires more time than comparable volume stages to manufacture. So, the concept is to build a new Rocket using off the shelf parts whenever possible, modified parts if changes need to be made, but minimal NEW parts.

The basic concept in detail: Take the Saturn S-II mid-stage combined with the Saturn S-IVB upper stage and make them a viable rocket. The 5 J-2 engines on the S-II stage do not generate enough thrust at sea level to lift the stack with more than 20,000lb of payload. This is lower than the Saturn IB. Then let's start looking for ways to boost the thrust at launch and get bigger payloads. We have 4 SRMs to choose from for this. The 66" (so about the size of the Agena) Minuteman first stage motor, and the UA-120x family from the Chemical Systems Division of United Aircraft Corporation (the US one not the post-

Soviet Russian one!) The Motors investigated from the UA-120x family are the UA-1204, the UA-1205 and the UA-1207. The UA-1206 did not exist at the time the Saturn II concept was investigated so it is not included.

What was investigated: Using the UA-1204, 5 and 7 in a 2x, or 4x SRMs. While many sources talk about 5x UA-1205s this is from either a different study or someone's extrapolation not under contract. Using the Minuteman 1st stage motor in combinations of 4 up to 12 total SRMs. And what combination of SRMs, J-2S (vacuum bell only) and SRMs would provide the largest payload, or the cheapest launch for X payload.

Saturn II with Minuteman SRMs for thrust augmentation:

Early in the concept definition phase it was determined it would be much safer to carry all empty Minuteman stages attached to the S-IC to S-II interstage skirt. The skirt was retained for improved low altitude drag reduction vs the open J-2 boat tail of the S-II Stage. This helped to keep exhaust gasses from any SRMs attached to the S-II stage away from the J-2 engines and reduced the chances of the J-2 engines receiving damage in the case of an SRM failure that was not catastrophic enough to result in a range destruction.

The Minuteman engines would be fired in groups of 2, 4, 6 or 12 depending on payload needs. The Minuteman enhanced Saturn II rocket was tied for best cost to 100 mile orbit with the S-II + 4x UA1204. This is in the 50,000 to 70,000 lbs to LEO (100 Mile) orbit. In every case the Saturn S-II stage is lit on the ground with any combination of SRMs ignited at launch to provide a 1.25 TWR at clamp release.

60,000lbs is about the most cost-effective point with the Minuteman SRMs. Using approximately 85% max fuel in the S-II stage and 90% fuel in the S-IVB stage, a 8 Minuteman boost arrangement in a 6 + 2 burn profile would be cost positive vs other Minuteman options for 60,000 lbs. For smaller and lighter payloads this was a preferred option, given less mass than 60,000 required a more extensive setup with extra Minuteman SRMs.

50,000lbs would utilize 2/3rds max fuel for the S-II stage, 95% max fuel for the S-IVB stage and 12 Minutemans in a 6 + 4 + 2 Burn profile. While more Minuteman SRMs were ignited to get less payload into space, the fuel costs for the Hydrolox outweighed the cost of purchasing extra Minuteman SRMs during the time of this study.

70,000lbs to space was about the upper end of this launch system and is less economical than some of the 120" SRM combinations. The S-II first stage is fully fueled. The S-IVB stage is at 95 to 97% max fuel. 12 SRMs in a 8 + 4 Burn profile are utilized for thrust augmentation. The maximum payload that the Saturn II rocket could attain with the Minuteman SRMs to that 100 Mile orbit was 75,000lbs

In the Final MLV papers, the combinations of the Minuteman SRM, the S-II stage and the S-IVB stage would be called INT-19.

Saturn II with 120" UA-1204 SRMs:

Only good for use at the lower end of the payload spectrum envisioned for the Saturn II. The UA-1204s were only studied using them in a 4x arrangement. With 50% S-II fuel and 100% S-IVB fuel, the Saturn II with UA-1204s would be good to get 43,000 to 51,000lbs to the 100nm orbit. The burn profile was significantly different than that of the Minuteman SRM equipped INT-19 above. Rather the UA-1204s would be ignited on the pad. A large air-dam Heat shield would be installed below the J-2S engines in this profile that would be jettisoned at 1st stage engine ignition. Like the Titan rockets previously carrying the UA-1205s the Saturn II in this configuration would ignite the J-2S engines about 7 seconds before SRM burn out. While this profile is only good for low mass items to space, it is the most cost-effective version of the Saturn II for launching sub 50,000lb payloads into space.

Saturn II UA-1205 configurations:

Carrying approximately 90% the max fuel in the S-II stage and 90% in the S-IVB stage, equipped with 4x UA-1205s, the Saturn II was good for 114,000lbs. This used an alternative ignition of the 2nd stage at the 70 second mark, rather than the 97 second mark. Yes we will get to lighter payloads in a minute.

Without the S-IVB, a 4x UA-1205 launched Saturn II was good for 86,000lbs with a fully loaded S-II stage. This was a 70 second S-II ignition point.

With 2x UA-1205 + a ground lit S-II stage with full fuel and a S-IVB stage with 90% max fuel the payload was good for 89,300lbs. The Acceleration is higher in this profile than in the above 86,000lb payload.

There is no easy way to use the UA-1205 SRMs to get a payload of less than 85,000lbs effectively.

Saturn II UA-1207 configurations:

2x UA-1207 + 60% S-II fuel and a full S-IVB would get 60,500lbs to space.

Same configuration except change the S-II stage fuel to 75% fuel and lighting the S-II stage on the ground increases payload capability to 78,000lbs

4x UA-1207, Full S-II and Full S-IVB is good for 146,500lbs to 100 Mile orbit. Second stage is ignited after 70 seconds of flight, or almost 3/4ths the way through the 104 second SRM burn.

4x UA-1207, full S-II and no S-IVB is good for 97,000lbs. Again burn of the S-II stage was started at 70 seconds of flight.

All of these Saturn II with the UTC UA-120x SRMs were classified under the Saturn INT-18 proposal in the Final NAA/Douglas reports to NASA.

The White Whale: The HG-3 x7 Equipped Saturn II INT-17. The HG-3 engine is a paper program. As such no proposal could be taken seriously when including the HG-3 in specifications. However, several documents refer to an “Advanced” engine during the MLV process. The Stage manufacturers were proposing hypothetical stages based on the progression of engine technology. This means the INT-17 is also just a paper study and offered as a comparison of what IMPROVED tech could gain. INT-17 with 7

Improved engines is quoted as 92,000lbs to 100 Mile orbit. This is in a 2 stage configuration with the 7 Improved Engines ignited on the ground with zero SRMs. Utilizing the RL-20-P3 with standard S-II tankage and a 7 engine mount closely approximates this performance.