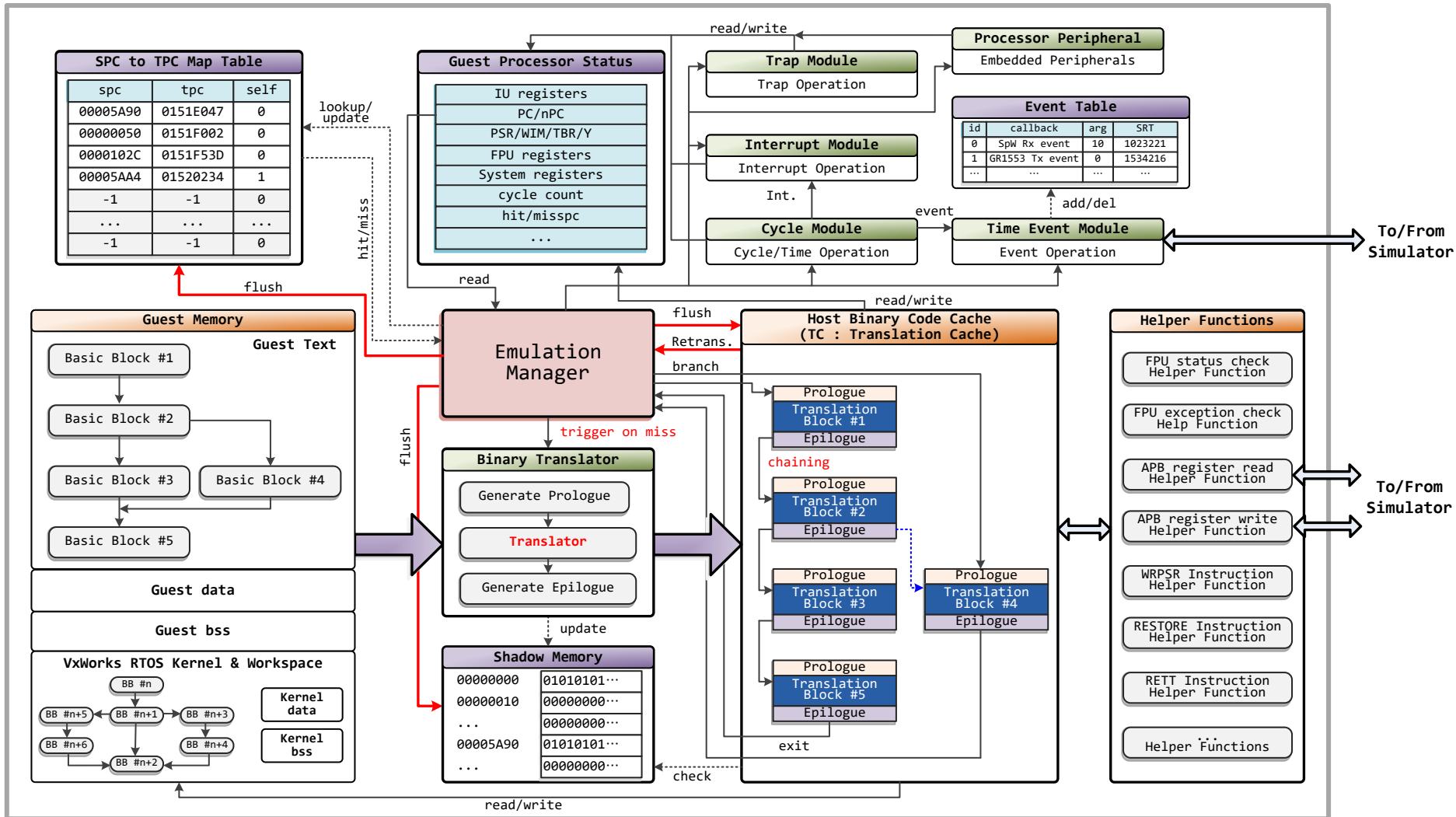
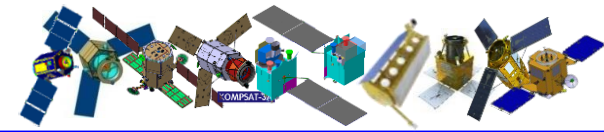


LAYSIM-GR740-MDBT (MULTI-THREAD DBT) FASTER THAN REAL-TIME

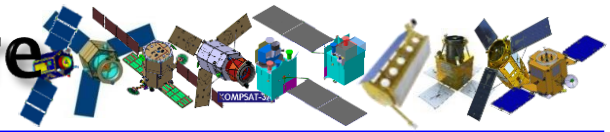
2021. 04. 22

Jong-Wook Choi
(jwchoi@kari.re.kr)

laysim-GR740-DBT Architecture

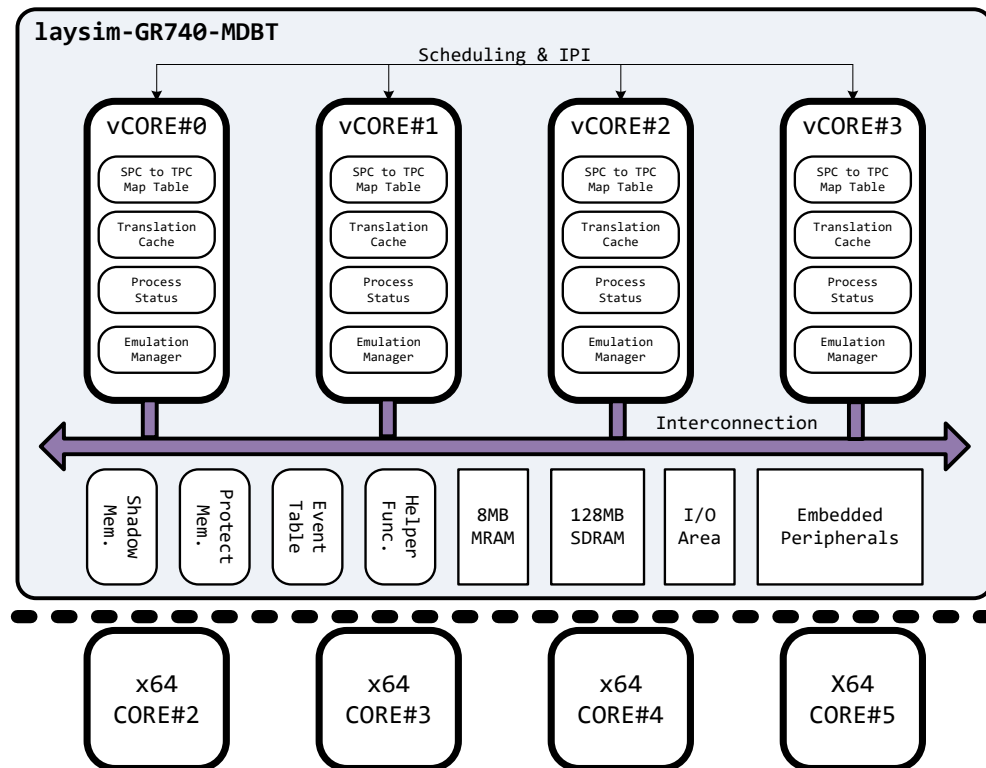


laysim-GR740-MDBT Architecture

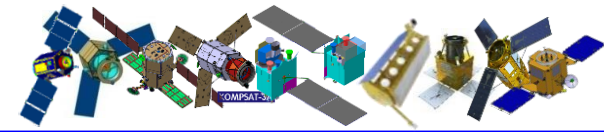


- **Features**

- Reuse mature laysim-GR740-DBT emulator (thread safe already)
- Decouple the complexity of supporting parallel emulation
 - Allocate 4 x64 cores for 4 GR740 cores (pthread affinity)
- Keep simulated cores in sync using time quantum (Default 500 cycles (2usec))
- Memory synchronization among vCOREs based on spin-lock using x64 cmpxchg

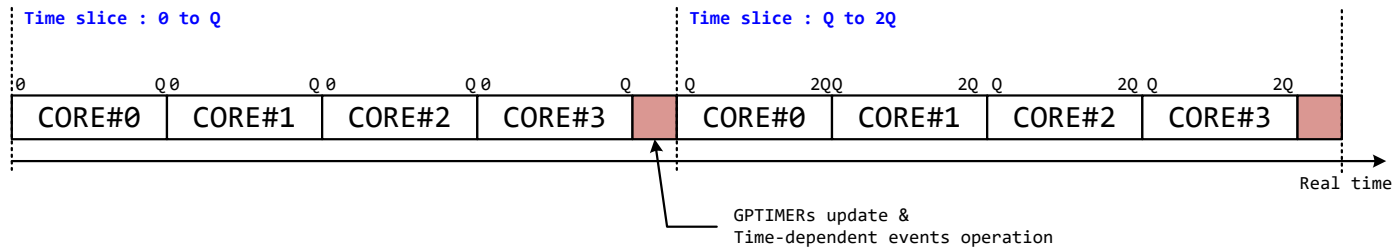


Multicore Scheduling



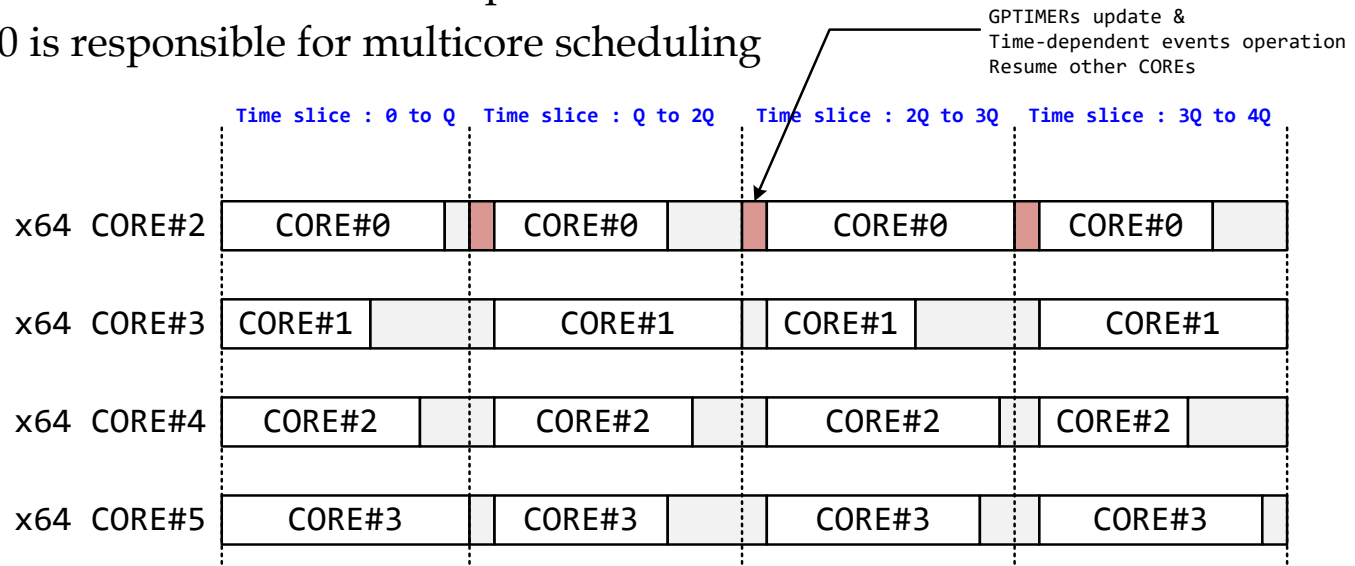
- laysim-GR740-DBT

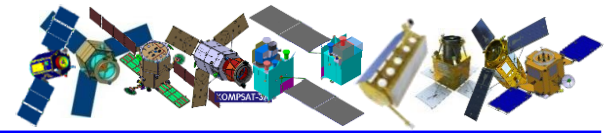
- Emulate multicore in a round-robin fashion based on time quantum
- GPTIMERS are updated and time-dependent events are serviced on completion



- laysim-GR740-MDBT

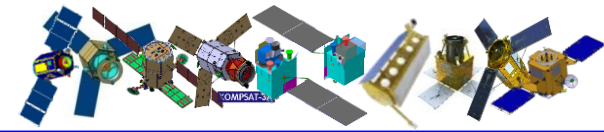
- Parallel execution based on time quantum
- CORE#0 is responsible for multicore scheduling





Evaluation

Test Environment

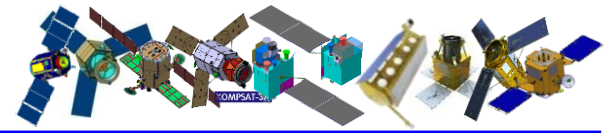


- **Host Computer**

- 11th Gen Intel Core i9-11900K @ 5GHz with hyper-threading enabled, 64GB RAM
- Run on Virtual Machine (CentOS 7 64bit) under VMWare Workstation 15 Pro
 - RAM : 8GB, Processors : 6 Cores, HDD : 200GB
- To get the best performance, you need a high-end computer

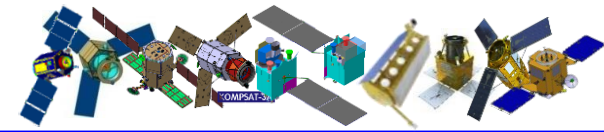
- **laysim-GR740-MMU version**

- The real-time performance of MMU version is somewhat lower than non-MMU version
- Because every memory access & FETCH need the address translation from virtual address to physical address with checking MMU exception



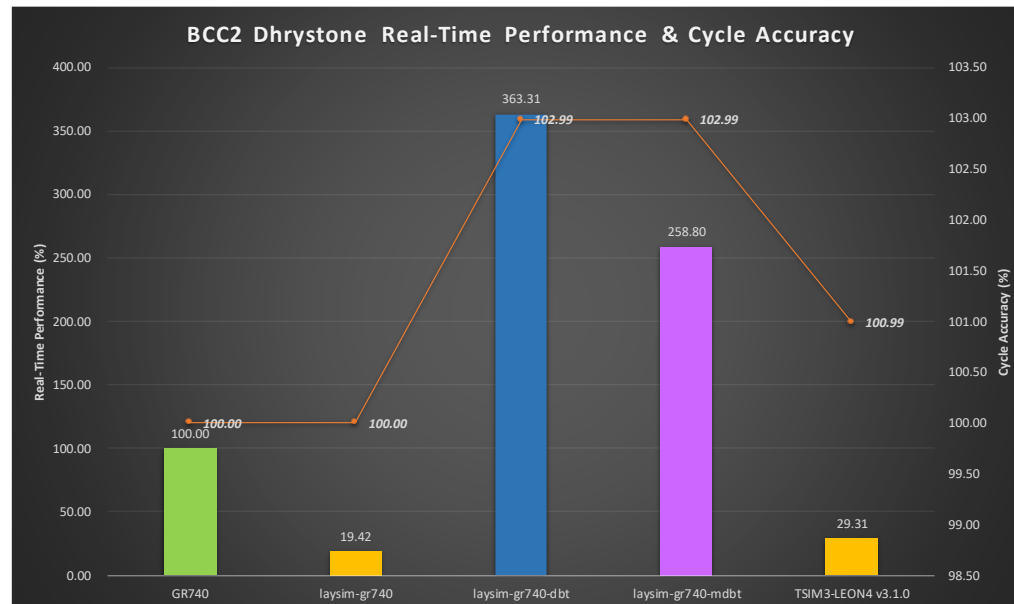
BCC 2.2.0 Examples

Dhrystone Result

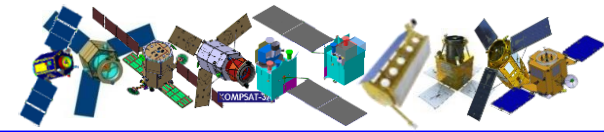


- **Single Dhrystone (Number_Of_Runs = 5000000)**
 - laysim-gr740-dbt shows best performance with 363.31% RTP (real-time performance)
 - laysim-gr740-mdbt is somewhat slower because of memory synchronization on write/atomic instructions

BCC2 Dhrystone	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	1719895165	8.681544972	198.11	100.00	2170386243	100.00
laysim-gr740	1719888601	44.7	38.48	19.42	2170361260	100.00
laysim-gr740-dbt	1719888601	2.38956	719.75	363.31	2235320660	102.99
laysim-gr740-mdbt	1719888601	3.3546	512.70	258.80	2235320660	102.99
TSIM3-LEON4 v3.1.0	1720914679	29.62	58.10	29.31	2191897752	100.99

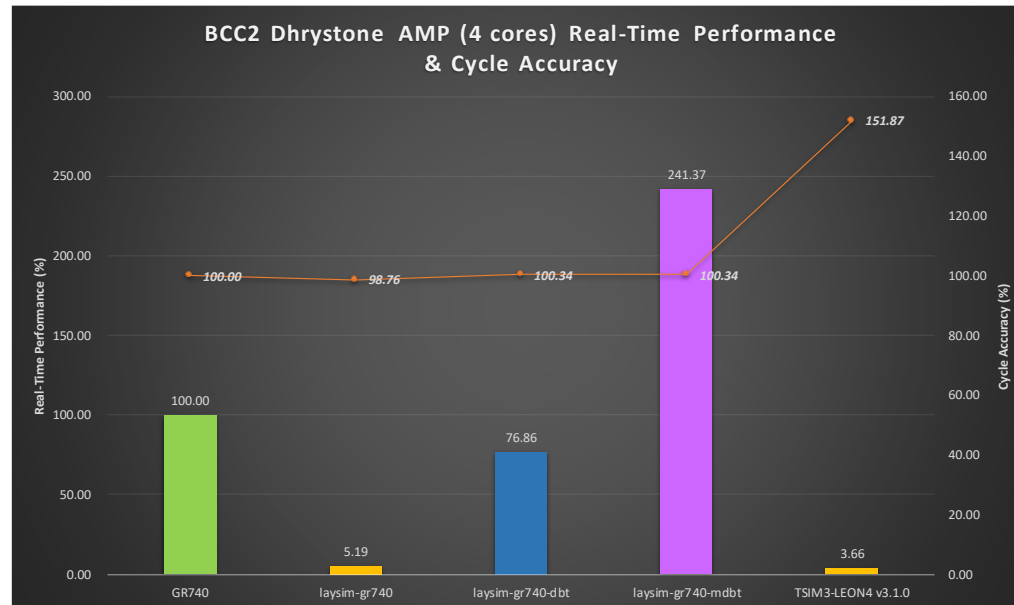


Dhrystone AMP 4 Cores Result

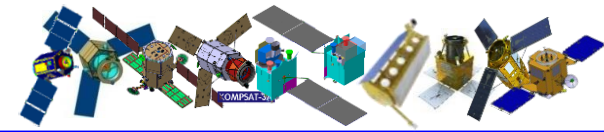


- Dhrystone AMP 4 Cores (Number_Of_Runs = 5000000)
 - laysim-gr740-mdbt outperforms the real-time performance of GR740 with 241.37% RTP
 - Dhrystone is a best example for dynamic binary translation because all SPARC codes are translated into x64 and the translated codes are only executed repeatedly

BCC2 Dhrystone AMP (4 cores)	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	6860013688	8.849787344	775.16	100.00	2212446836	100.00
laysim-gr740	6860001805	170.546	40.22	5.19	2185120264	98.76
laysim-gr740-dbt	6860001805	11.5135	595.82	76.86	2220016428	100.34
laysim-gr740-mdbt	6860001805	3.66654	1870.97	241.37	2220016428	100.34
TSIM3-LEON4 v3.1.0	6860005180	242.01	28.35	3.66	3360099280	151.87

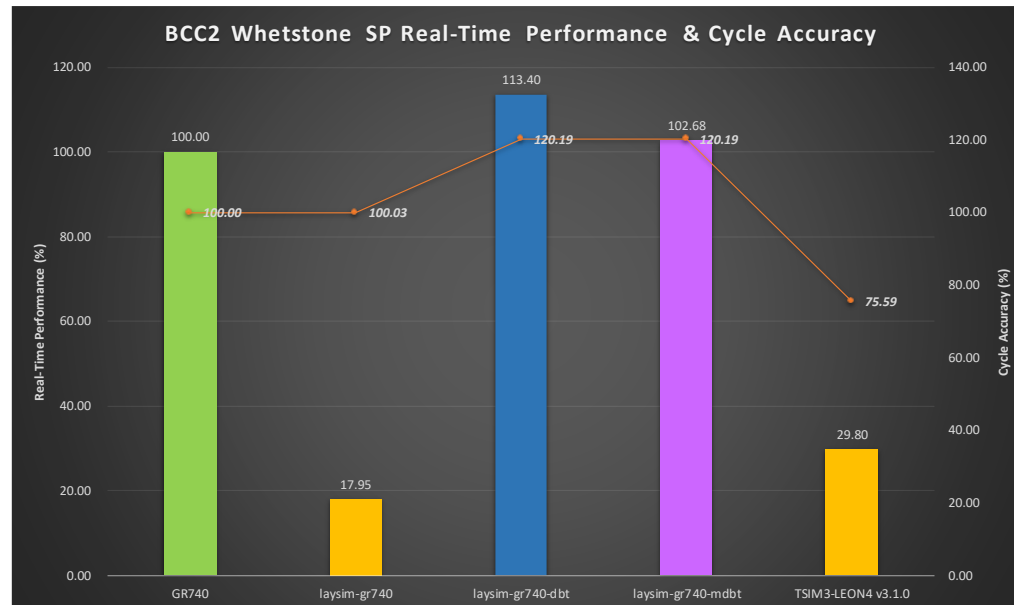


Whetstone Result

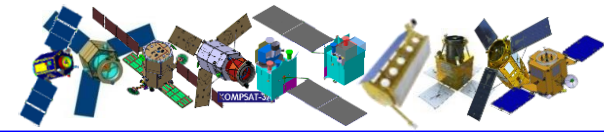


- **Single Whetstone (xtra = 100)**
 - laysim-gr740-dbt shows best performance with 113.40% RTP
 - laysim-gr740-mdbt is somewhat slower because of memory synchronization on write/atomic instructions

BCC2 Whetstone SP	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	1749566397	14.34772984	121.94	100.00	3586932459	100.00
laysim-gr740	1749513279	79.9456	21.88	17.95	3587876518	100.03
laysim-gr740-dbt	1749513279	12.6526	138.27	113.40	4311010989	120.19
laysim-gr740-mdbt	1749513279	13.9738	125.20	102.68	4311010989	120.19
TSIM3-LEON4 v3.1.0	1760197695	48.15	36.56	29.80	2711273590	75.59



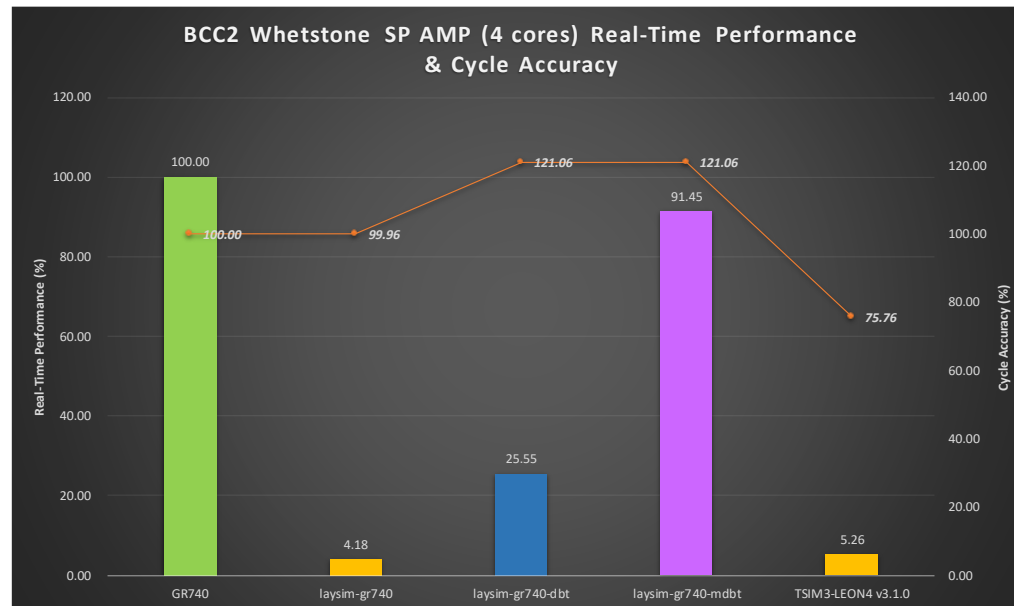
Whetstone AMP 4 Cores Result

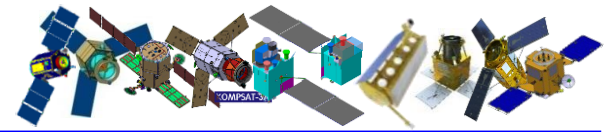


- **Whetstone AMP 4 Cores (xtra = 100)**

- laysim-gr740-mdbt satisfied near the real-time performance of GR740 with 91.45% RTP
- FPU emulation takes more timer because it should check FPU registers, result and exception according to its mask

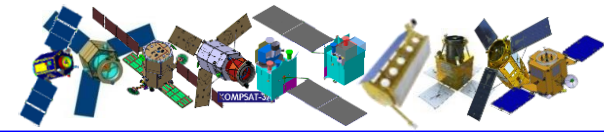
BCC2 Whetstone AMP (4 cores)	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	6799170779	13.72682116	495.32	100.00	3431705289	100.00
laysim-gr740	6799170538	328.272	20.71	4.18	3430375252	99.96
laysim-gr740-dbt	6799170538	53.7334	126.54	25.55	4154575867	121.06
laysim-gr740-mdbt	6799170538	15.0098	452.98	91.45	4154575867	121.06
TSIM3-LEON4 v3.1.0	6799165583	261.18	26.03	5.26	2599854513	75.76





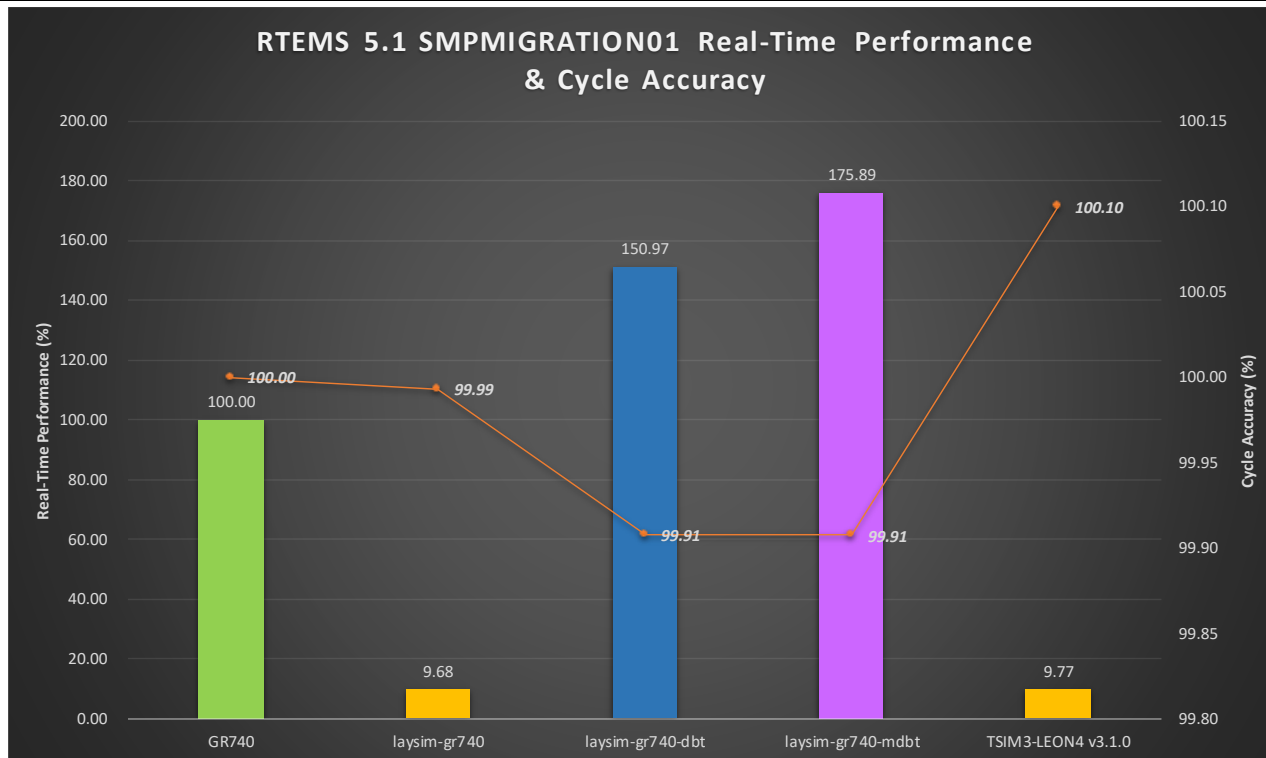
RTEMS 5.1 SMPTEST Examples

SMPMIGRATION01 Result

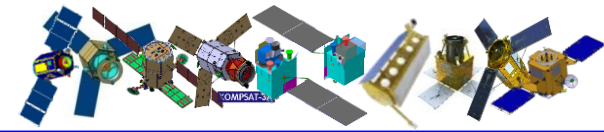


- RTEMS 5.1 SMPMIGRATION01
 - laysim-gr740-dbt and -mdbt can satisfy the RTP of GR740

RTEMS 5.1 smpmigration01	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	2952228461	10.29442261	286.78	100.00	2573605653	100.00
laysim-gr740	3057834610	106.358	28.75	9.68	2573429219	99.99
laysim-gr740-dbt	3057834610	6.81875	448.45	150.97	2571229182	99.91
laysim-gr740-mdbt	3057834610	5.85264	522.47	175.89	2571220203	99.91
TSIM3-LEON4 v3.1.0	2930430734	105.32	27.82	9.77	2576170918	100.10



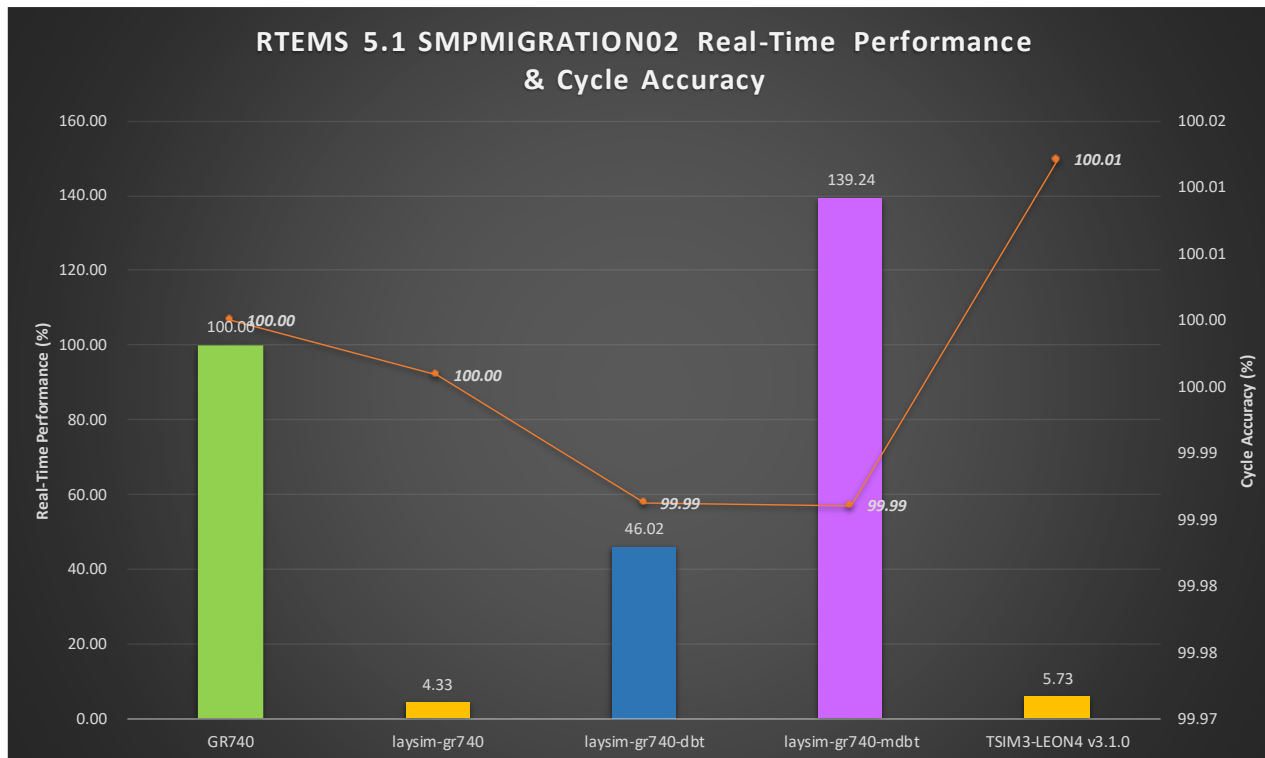
SMPMIGRATION02 Result



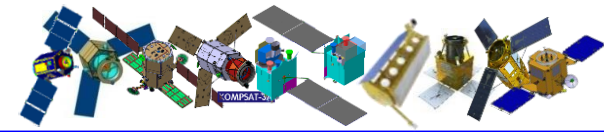
- RTEM5 5.1 SMPMIGRATION02

- Only laysim-gr740-mdbt can meet the RTP of GR740 with 139.24% RTP

RTEM5 5.1 smpmigration02	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	13486479698	30.11275333	447.87	100.00	7528188332	100.00
laysim-gr740	13935725271	696.155	20.02	4.33	7527877888	100.00
laysim-gr740-dbt	13935725271	65.428	212.99	46.02	7527154681	99.99
laysim-gr740-mdbt	13935725271	21.627	644.37	139.24	7527138839	99.99
TSIM3-LEON4 v3.1.0	10075833121	525.53	19.17	5.73	7529098329	100.01



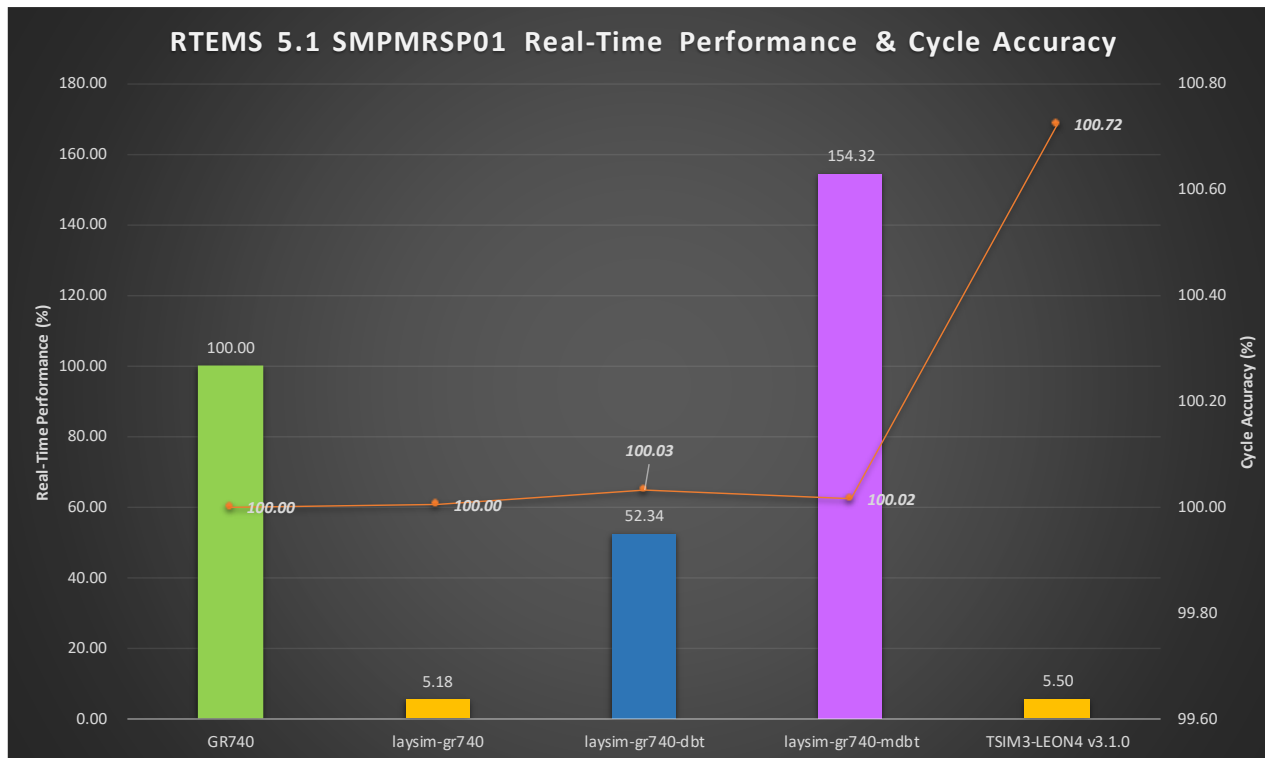
SMPMRSP01 Result



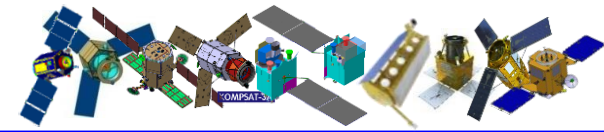
- RTEMS 5.1 SMPMRSP01

- Only laysim-gr740-mdbt can meet the RTP of GR740 with 154.32% RTP

RTEMS 5.1 smpmrsp01	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	15626987938	32.36153462	482.89	100.00	8090383654	100.00
laysim-gr740	15859053353	624.645	25.39	5.18	8090744573	100.00
laysim-gr740-dbt	15859053353	61.8305	256.49	52.34	8092858782	100.03
laysim-gr740-mdbt	15859053353	20.9708	756.24	154.32	8091642384	100.02
TSIM3-LEON4 v3.1.0	14621756291	588.72	24.84	5.50	8148869528	100.72



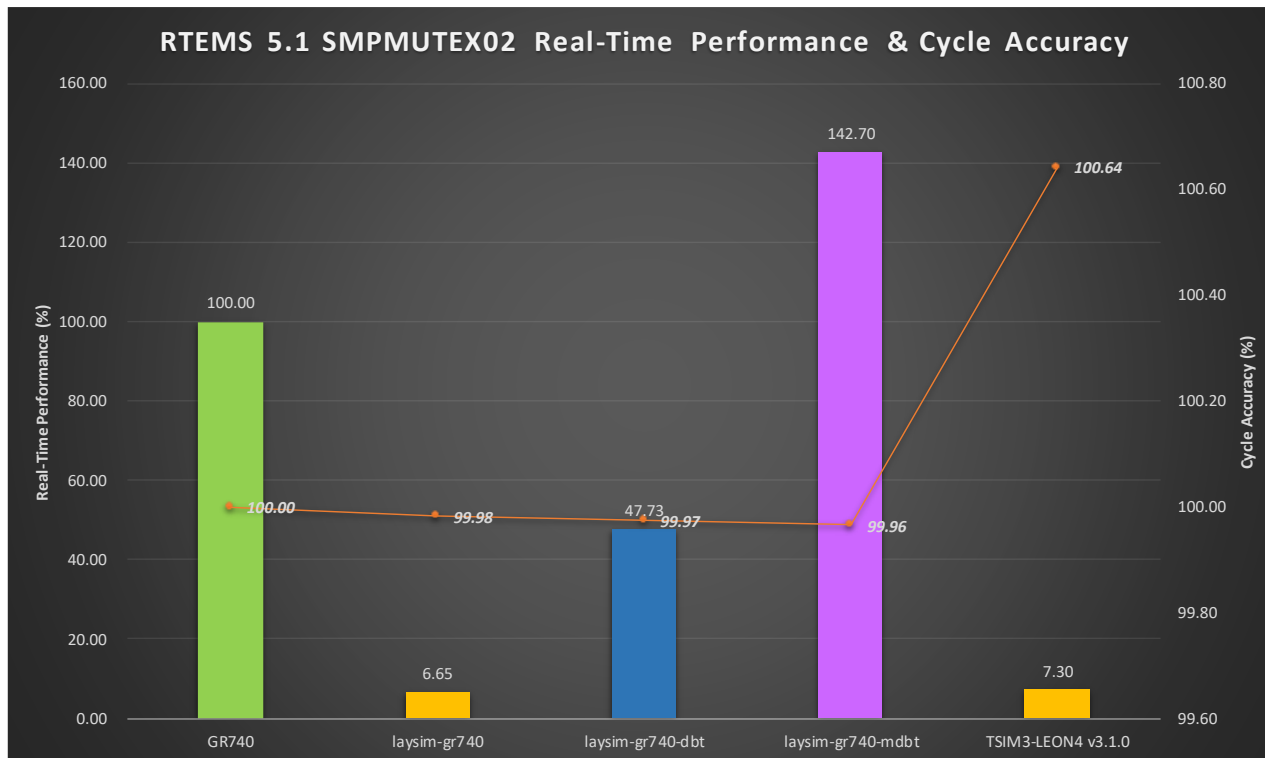
SMPMUTEX02 Result



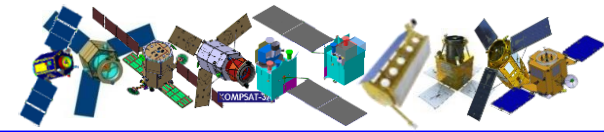
- RTEMS 5.1 SMPMUTEX02

- Only laysim-gr740-mdbt can meet the RTP of GR740 with 142.70% RTP

RTEMS 5.1 smpmutex02	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	3071415305	10.71495242	286.65	100.00	2678738105	100.00
laysim-gr740	3340812554	161.065	20.74	6.65	2678248373	99.98
laysim-gr740-dbt	3340812554	22.4496	148.81	47.73	2678034187	99.97
laysim-gr740-mdbt	3340812554	7.50886	444.92	142.70	2677799848	99.96
TSIM3-LEON4 v3.1.0	3152707775	146.85	21.47	7.30	2695918280	100.64



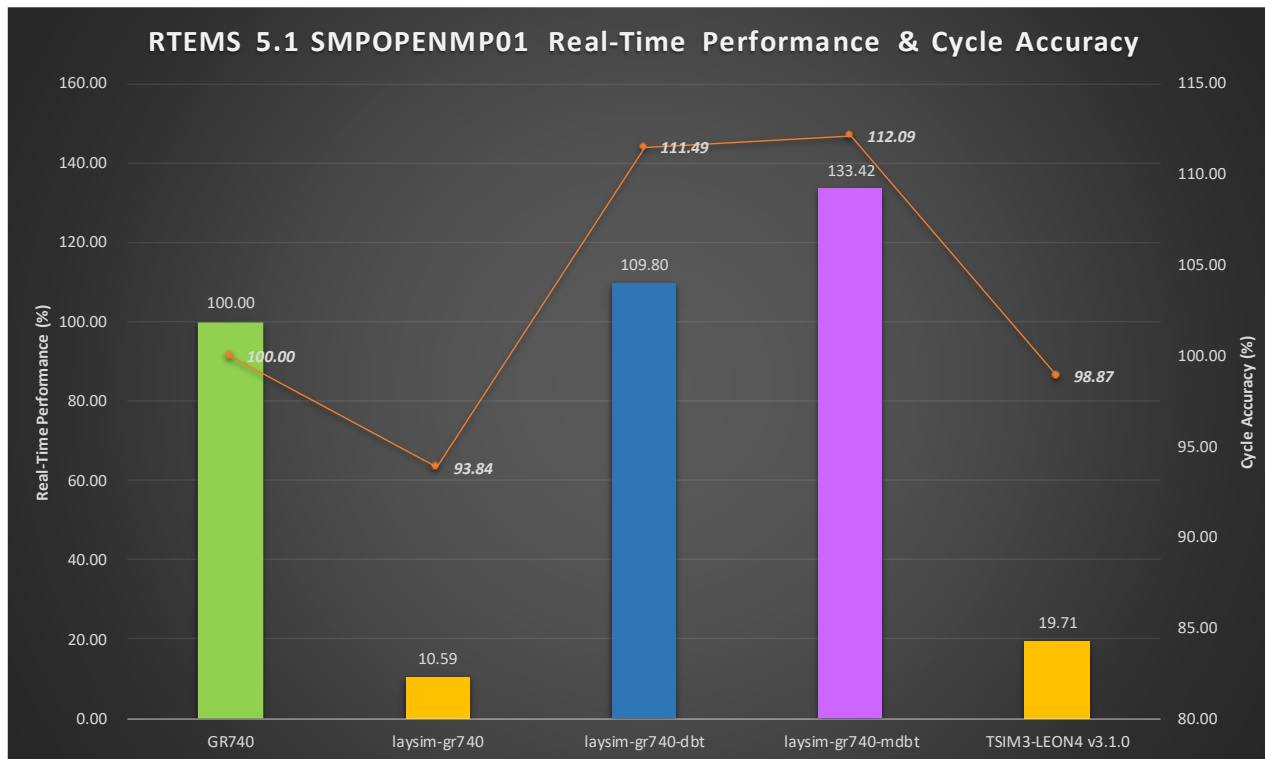
SMPOPENMP01 Result



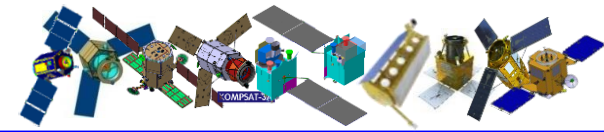
- **RTEMS 5.1 SMPOPENMP01**

- laysim-gr740-dbt and -mdbt can meet the RTP of GR740

RTEMS 5.1 smpopenmp01	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	3536631677	10.93448786	323.44	100.00	2733621966	100.00
laysim-gr740	3479696160	103.234	33.71	10.59	2565134686	93.84
laysim-gr740-dbt	3479696160	9.95832	349.43	109.80	3047788622	111.49
laysim-gr740-mdbt	3479696160	8.19582	424.57	133.42	3064251322	112.09
TSIM3-LEON4 v3.1.0	6767387845	55.47	122.00	19.71	2702865027	98.87



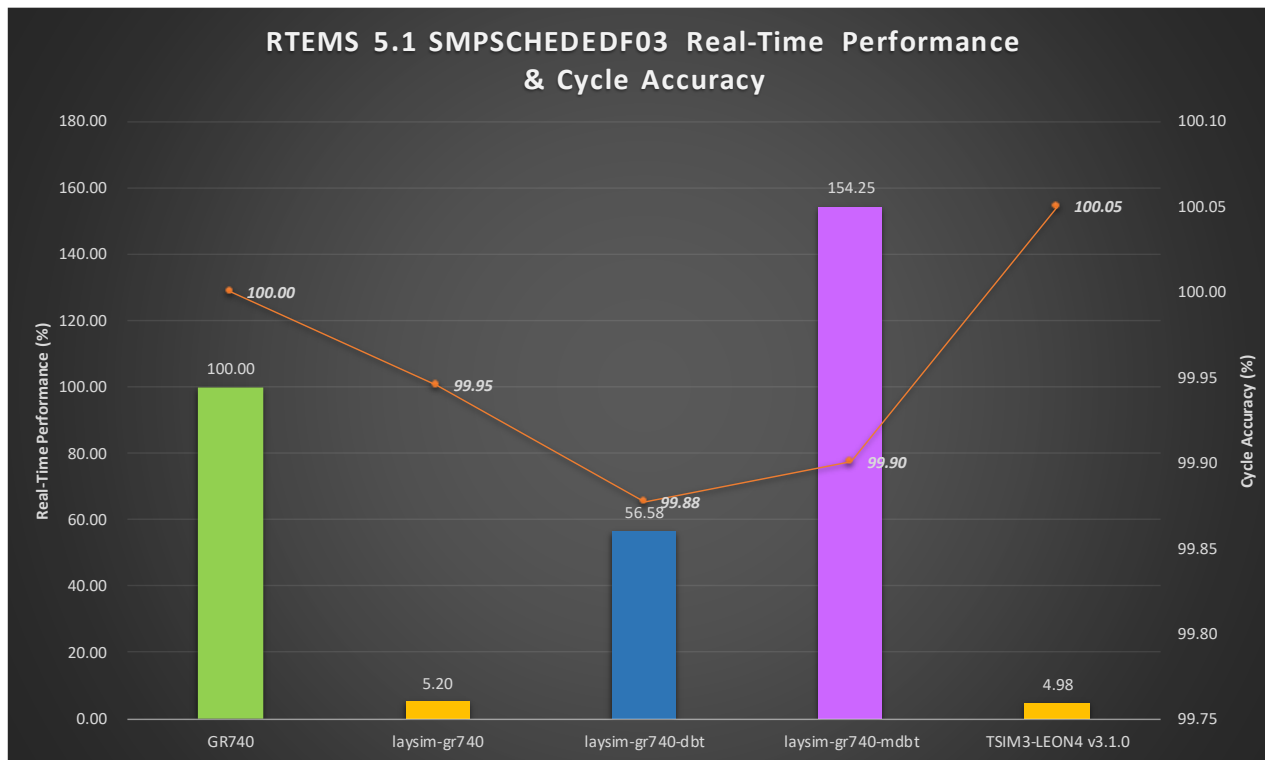
SMPSCHEDDF03 Result



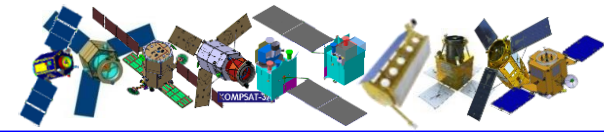
- RTEMS 5.1 SMPSCHEDDF03

- Only laysim-gr740-mdbt can meet the RTP of GR740 with 154.25% RTP

RTEMS 5.1 smpscheddf03	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	6052753639	10.09287466	599.71	100.00	2523218666	100.00
laysim-gr740	6325610537	194.204	32.57	5.20	2521850580	99.95
laysim-gr740-dbt	6325610537	17.8387	354.60	56.58	2520112950	99.88
laysim-gr740-mdbt	6325610537	6.5432	966.75	154.25	2520703178	99.90
TSIM3-LEON4 v3.1.0	5930255438	202.68	29.26	4.98	2524487228	100.05



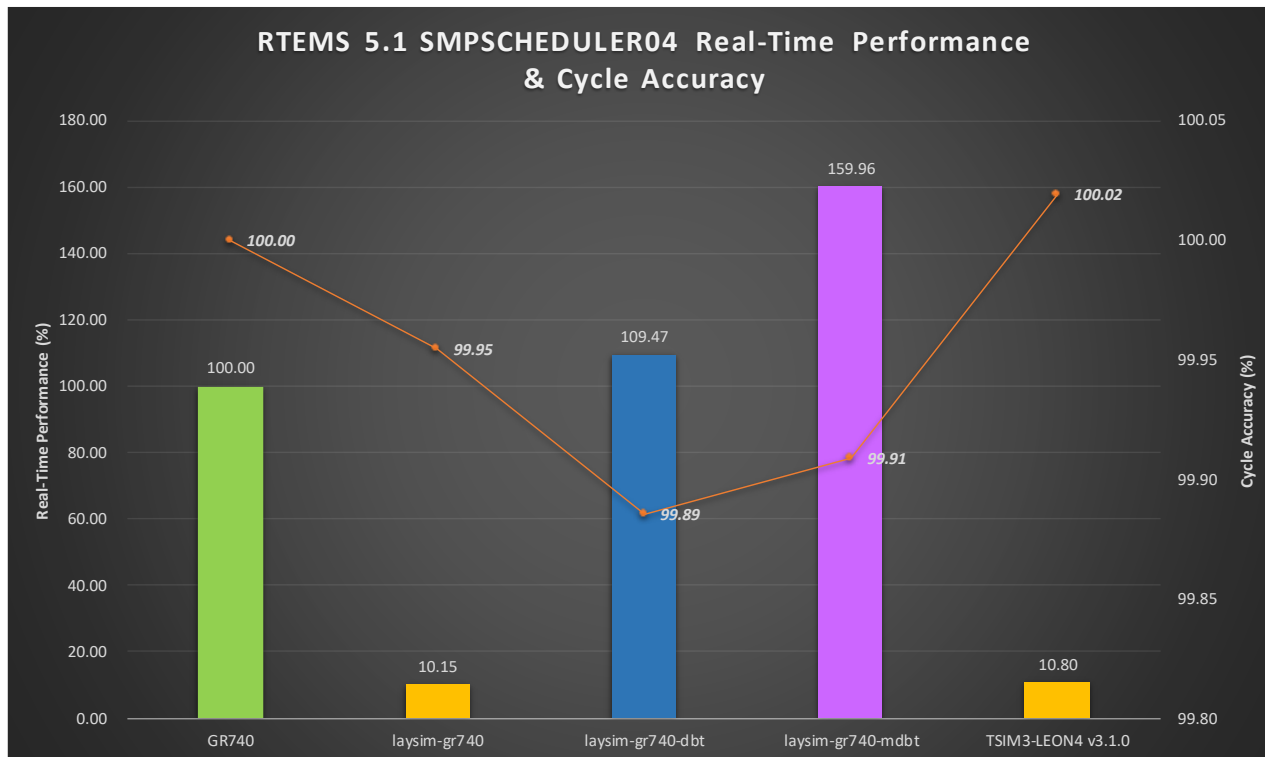
SMPSCHEDULER04 Result



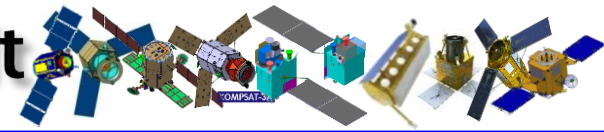
- RTEMS 5.1 SMPSCHEDULER04

- laysim-gr740-dbt and -mdbt can meet the RTP of GR740

RTEMS 5.1 smpscheduler04	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	2326226331	10.09200362	230.50	100.00	2523000904	100.00
laysim-gr740	2401288163	99.4027	24.16	10.15	2521850580	99.95
laysim-gr740-dbt	2401288163	9.21921	260.47	109.47	2520112950	99.89
laysim-gr740-mdbt	2401288163	6.3091	380.61	159.96	2520703178	99.91
TSIM3-LEON4 v3.1.0	2207640178	93.47	23.62	10.80	2523488127	100.02



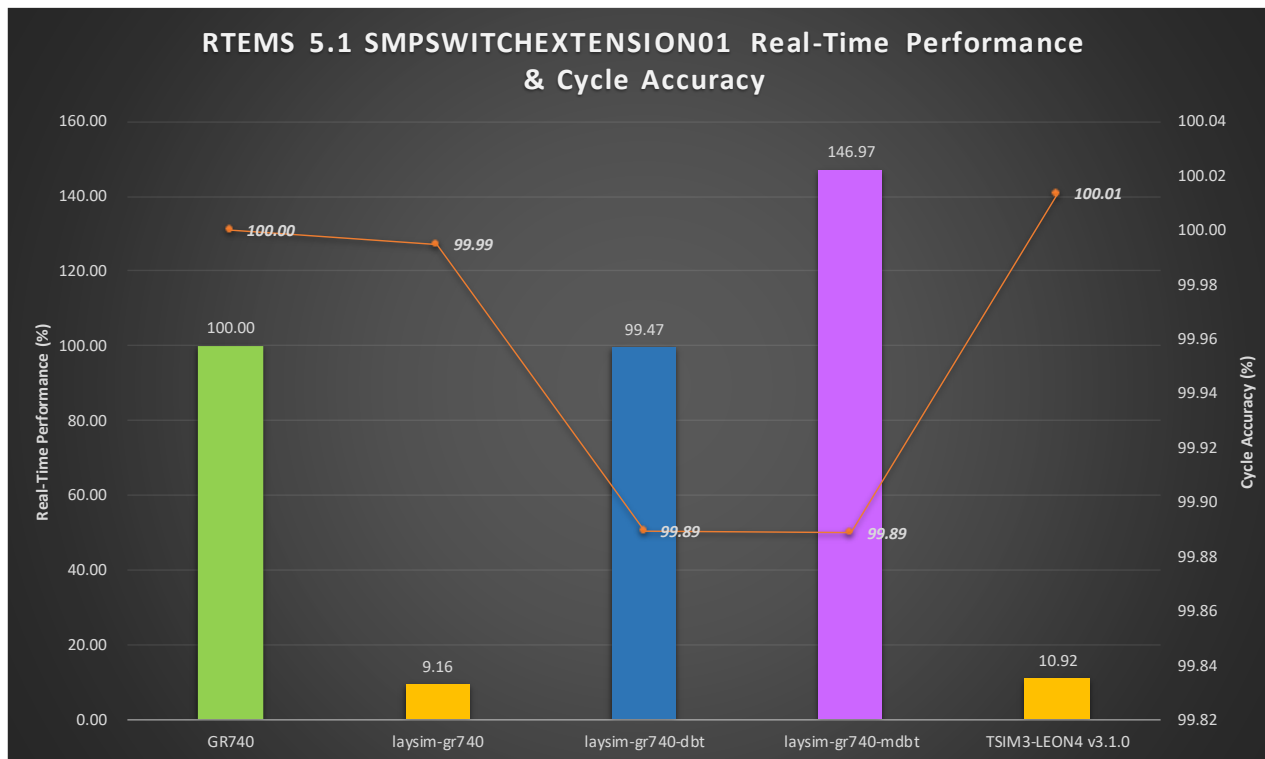
SMPSWITCHEXTENSION01 Result



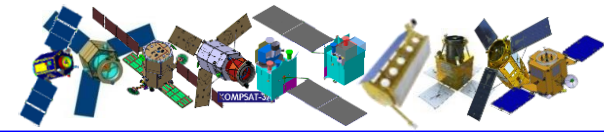
- RTEMS 5.1 SMPSWITCHEXTENSION01

- Only laysim-gr740-mdbt can meet the RTP of GR740 with 146.97% RTP

RTEMS 5.1 smpswitchextension01	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	2788532184	10.2040047	273.28	100.00	2551001176	100.00
laysim-gr740	2939298388	111.445	26.37	9.16	2550873398	99.99
laysim-gr740-dbt	2939298388	10.2587	286.52	99.47	2548175553	99.89
laysim-gr740-mdbt	2939298388	6.94273	423.36	146.97	2548165131	99.89
TSIM3-LEON4 v3.1.0	2721589448	93.47	29.12	10.92	2551345014	100.01



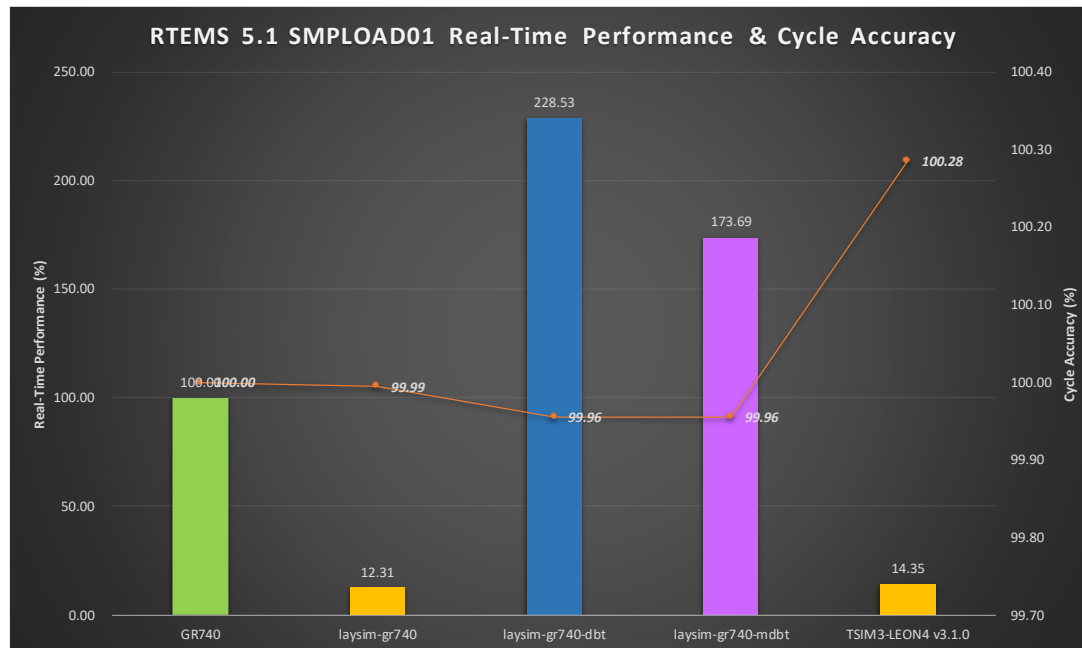
SMPLOAD01 Result



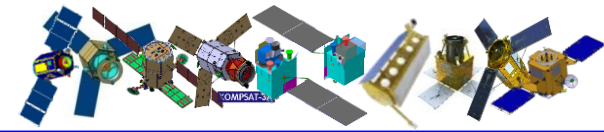
- **RTEMS 5.1 SMPLOAD01**

- laysim-gr740-dbt and -mdbt can meet the RTP of GR740
- In this case, -mdbt shows more lower performance than -dbt because of excessive memory synchronization in x64 from SWAP/CASA instructions

RTEMS 5.1 smpload01	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	9271693244	31.00472659	299.04	100.00	7751181647	100.00
laysim-gr740	9356807923	251.807	37.16	12.31	7750735447	99.99
laysim-gr740-dbt	9356807923	13.567	689.67	228.53	7747746610	99.96
laysim-gr740-mdbt	9356807923	17.8508	524.17	173.69	7747731941	99.96
TSIM3-LEON4 v3.1.0	9281294899	216.02	42.96	14.35	7773231286	100.28



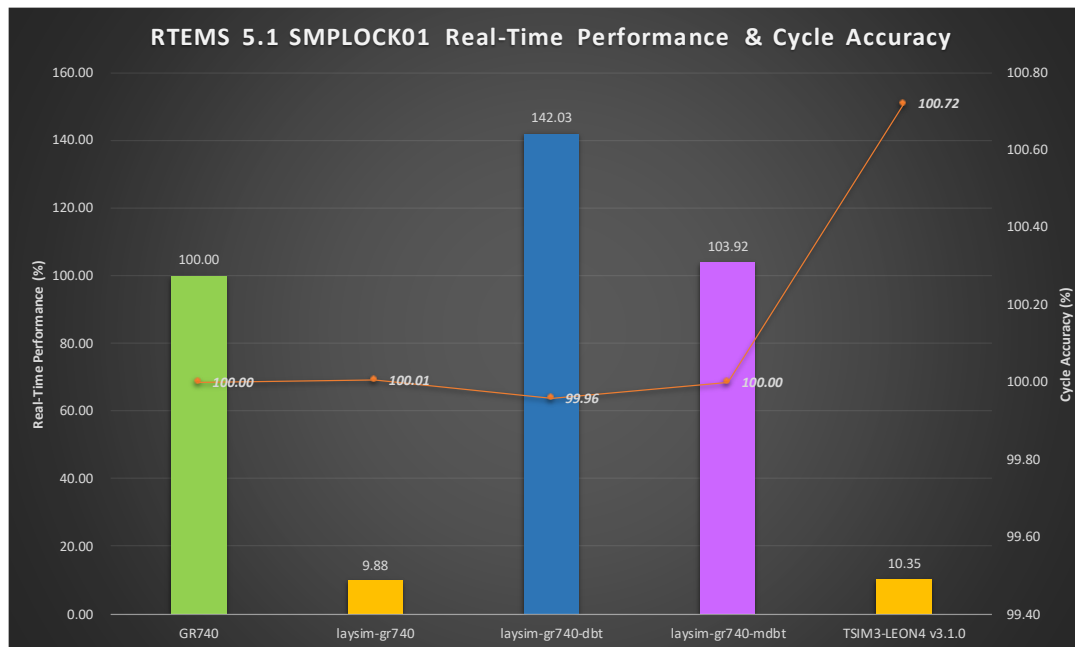
SMPLOCK01 Result



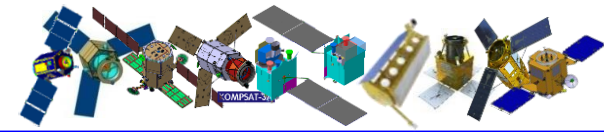
- **RTEMS 5.1 SMPLOCK01**

- laysim-gr740-dbt and -mdbt can meet the RTP of GR740
- In this case, -mdbt shows more lower performance than -dbt because of excessive memory synchronization in x64 from SWAP/CASA instructions

RTEMS 5.1 smplock01	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	17383489538	33.64903919	516.61	100.00	8412259798	100.00
laysim-gr740	17378769166	340.462	51.04	9.88	8412752757	100.01
laysim-gr740-dbt	17378769166	23.6919	733.53	142.03	8408771015	99.96
laysim-gr740-mdbt	17378769166	32.3802	536.71	103.92	8412229179	100.00
TSIM3-LEON4 v3.1.0	16676395573	325.16	51.29	10.35	8472886687	100.72



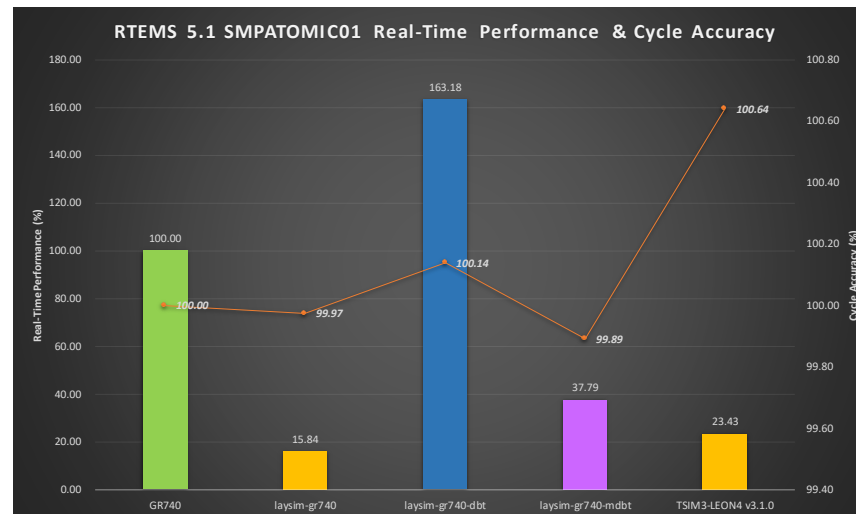
SMPATOMIC01 Result

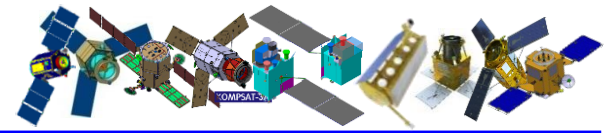


• RTEMS 5.1 SMPATOMIC01

- laysim-gr740-mdbt cannot meet the RTP of GR740 and it shows worst performance
- Because SMPATOMIC01 is an example that continuously executes only atomic instructions such as LDSTUB/CASA
- In this case, spin-locks are continuously used for memory synchronization in x64, and eventually race conditions occur, so the RTP of laysim-gr740-mdbt is rapidly degraded

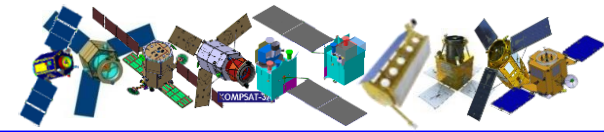
RTEMS 5.1 smpatomic01	# of INST	Wall Clock (sec)	RAW MIPS	Real-Time Performance (%)	Cycles	Cycle Accuracy (%)
GR740 (250MHz)	1230990307	8.520718824	144.47	100.00	2130179706	100.00
laysim-gr740	2201169987	53.8064	40.91	15.84	2129629730	99.97
laysim-gr740-dbt	2201169987	5.2218	421.53	163.18	2133099958	100.14
laysim-gr740-mdbt	2201169987	22.5475	97.62	37.79	2127824063	99.89
TSIM3-LEON4 v3.1.0	1421722480	36.36	39.10	23.43	2143796990	100.64





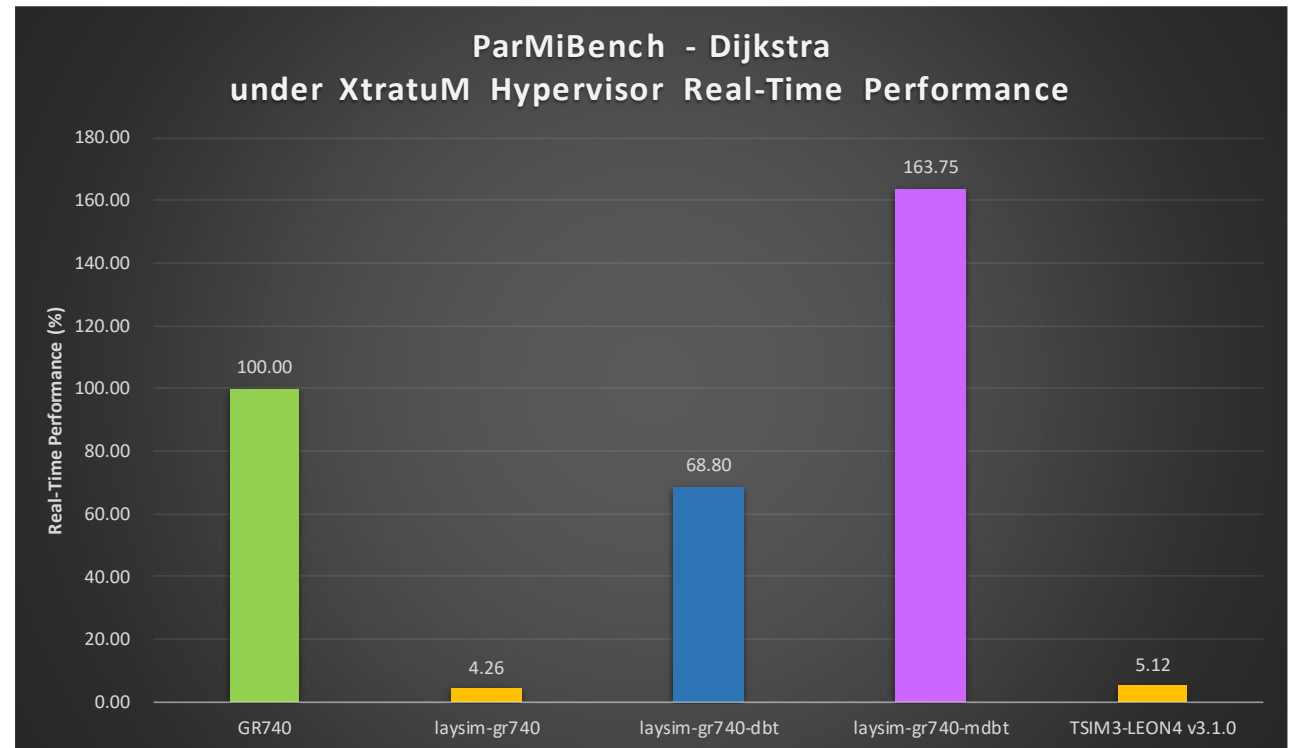
Xtratum 4.6 r1 Examples

ParMiBench - Dijkstra Result

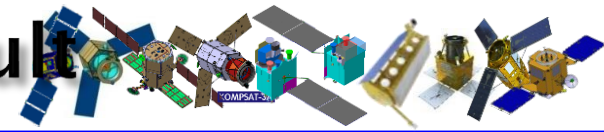


- ParMiBench - Dijkstra under XtratuM Hypervisor
 - Only laysim-gr740-mdbt can meet the RTP of GR740 with 163.75% RTP

XtratuM - Dijkstra	Wall Clock (sec)	Real-Time Performance (%)
GR740 (250MHz)	17.21210754	100.00
laysim-gr740	404.48	4.26
laysim-gr740-dbt	25.0191	68.80
laysim-gr740-mdbt	10.5109	163.75
TSIM3-LEON4 v3.1.0	336.43	5.12



ParMiBench - String Search Result



- ParMiBench - String Search under XtratuM Hypervisor
 - laysim-gr740-dbt and -mdbt can meet the RTP of GR740

XtratuM - String Search	Wall Clock (sec)	Real-Time Performance (%)
GR740 (250MHz)	75.89	100.00
laysim-gr740	505.502	15.01
laysim-gr740-dbt	38.0058	199.68
laysim-gr740-mdbt	19.3129	392.95
TSIM3-LEON4 v3.1.0	98.46	77.08

