

CS452 Train Control 2

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1 Running the program

We have two versions of our code that we would like to submit. One performs shortest-path routing (including reversals) for a single train, while the other routes multiple trains in a controlled manner using reservations.

The program initializes for the first four to five seconds of execution. Please don't quit the program during this period. If you do, you will likely see an assertion failure on the next run.

1.a Shortest-path routing

```
load -b 0x00218000 -h 10.15.167.5 "ARM/csulshoe/t2-shortest-path-routing.elf"
go
```

The ELF file for this version is stored at `/u/cs452/tftp/ARM/csulshoe/t2-shortest-path-routing.elf` in the CS Student Computing Environment. The source code can be found at <https://git.uwaterloo.ca/csulshoe/cs452/tree/shortest-path-routing>.

To test this version, use the `loop` command to accelerate the train to a constant speed, then the `route` command to route it to a location.

1.b Reservations

```
load -b 0x00218000 -h 10.15.167.5 "ARM/csulshoe/t2-reservations.elf"
go
```

The ELF file for this version is stored at `/u/cs452/tftp/ARM/csulshoe/t2-reservations.elf` in the CS Student Computing Environment. The source code can be found at <https://git.uwaterloo.ca/csulshoe/cs452/tree/reservation-based-route-execution>.

To test this version, use the `t2start` command to tell trains to route to random locations.

2 Commands

Command	Description
tr <train_number> <train_speed>	Set a train's speed.
rv <train_number>	Reverse a train.
sw <turnout_number> <turnout_direction>	Switch a turnout.
sd <train_number> <train_speed>	Run automated stopping distance calibration.
v <train_number>	Run automated velocity calibration.
loop <train_number> <train_speed>	Enter a loop around the track.
r <train_number> <sensor> <offset>	Stop at a location.
t2start <train_number>	Start random repeated routing.
t2stop <train_number>	Stop random repeated routing.
go	Start the train controller.
stop	Stop the train controller.
q	Quit.

3 Implementation

3.a Transfer acceleration model

We set out to build a model of the train's acceleration between two speeds in the case where the second speed is not zero. To accomplish this, we began building a task that would constantly monitor sensor data and train commands, looking for a train speed command that was run between two sensor hits. In this case, we can use our velocity model, the distance between the sensors, and the time it took to travel between them to determine the acceleration between the two speeds.

Unfortunately, we were unable to complete this feature. For now, we are calculating transfer acceleration based on the stopping acceleration of each train.

3.b Incremental switching

As a train moves along a route, it continuously switches turnouts within its stopping distance (plus a padding), instead of switching all turnouts at the start of route execution. This allows us to have a more granular reservation model.

3.c Short moves

To execute a short move, we calculate a train's stopping distance by linearly interpolating the stopping distances of the two nearest speeds (based on the velocity model). This allows us to keep the T1 behaviour of stopping the train once it has reached one stopping distance from its destination.

3.d Routing with reversal

We extended our implementation of Dijkstra's algorithm to take into account reversing at arbitrary track nodes. We also started to change route execution to handle reversal. If a train sees a reversal on its route within its stopping distance, it stops, reverses, and restarts. If the reversal happens on a turnout, it also switches the turnout before stopping, in order to go down the other branch of the turnout after reversing and restarting. Unfortunately, this feature is only partially functional.

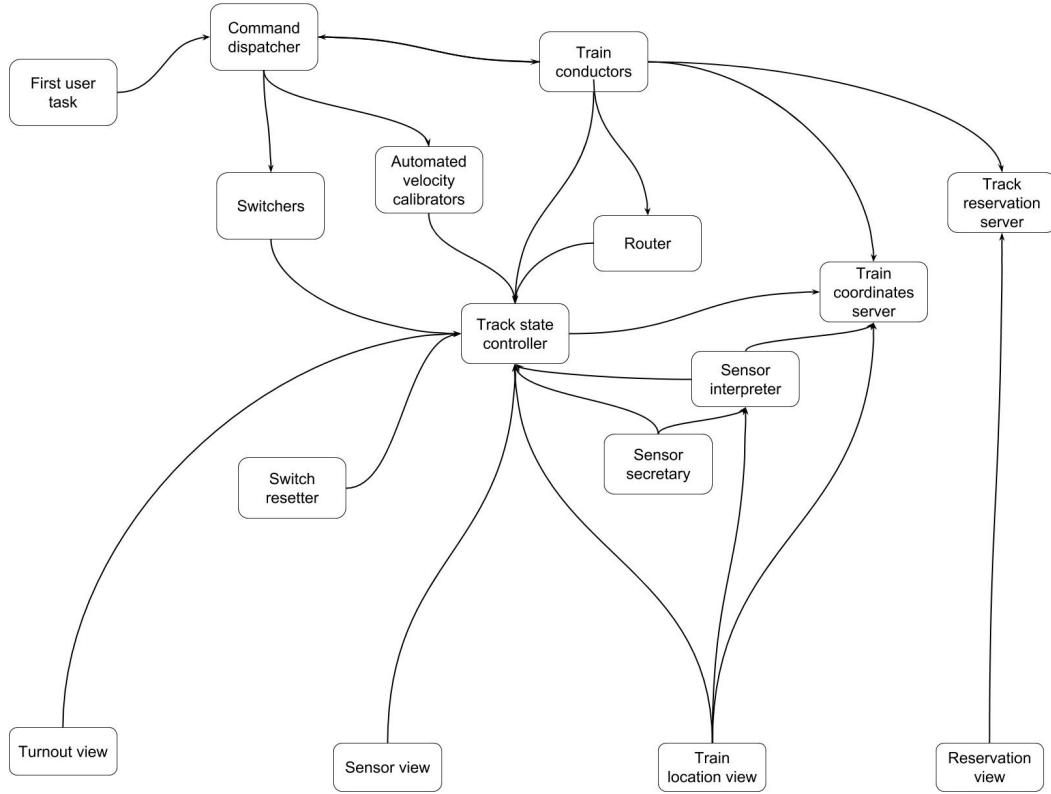


Figure 1: Diagram of our T2 task structure, with arrows indicating **Send** calls between tasks.

3.e Reservations

We also added a reservation system. A reservation server hands out edges between track nodes to trains. Trains continuously reserve track segments one stopping distance ahead of themselves on their routes. If a train determines that it can't reserve a track segment ahead of itself, it immediately stops. It then waits an amount of time based on its train number and tries to reserve ahead of itself again. If this process fails five times in a row, the train reverses and finds another route to the destination.

4 Task structure

Note that the graph above is a DAG except for **Sends** between the command dispatcher and the train conductors. These **Sends** happen in a controlled fashion; in particular, the command dispatcher only ever sends to a train conductor if it is ready for a new train command and is thus send-blocked. In this way, we hope to make deadlock less likely.

5 File and repository hashes

5.a Shortest-path routing

The last commit on the branch `shortest-path-routing` has SHA `214f0d703b90898fb3f91342e272a7704ffd1b16`.

5.a.1 MD5 hashes

```
git ls-files | grep -v 'test/googletest' | xargs md5sum
a5ab21bd63e960032282b0c6006de5cc .gitignore
4bbdec35a4b9dc9ca8615b1e321de502 .gitmodules
58bb9fbcf62dc59a35491ac53f0b612a .travis.yml
cddb7fbeb502f2adcba5aeb12b7e8e8c Doxyfile
cdf6332b45d1e86e90780570b2f751c8 Makefile
72528caa4dc861d6f0f2590e0aac6000 PULL_REQUEST_TEMPLATE.md
db17664126ec304585d152833b41ab72 README.md
ffffb471c0ef031de7290e9803a651aac gcc-ld
d7810fab7487fb0aad327b76f1be7cd7 gcc-ldCOPYING
10b31708f10ca2e4a77d04495578cb8b include/bwio.c
1506ac36c03fc3c02a62124aec4dbf20 include/bwio.h
1e06c47ed88775686330932eb570b056 include/io.h
28fb38ae413a58784deb9e362e2e56d0 include/myio.c
93cdb176a9db6bf6073d3f9ec5996df7 include/myio.h
0ff6bee28590e1b949a208361291deab include/mytimer.c
8958f41681273f9891540bc5289bb6e4 include/mytimer.h
9e66057d63ac6141d27d3f7d627298b8 include/rawio.c
2314714decf98c1fde63b96f2ffaf2ab include/rawio.h
a51b441bd12f84e40333d2dfde291780 include/timer_data.h
74c63a11fc85af6c146dbcb5fa19b14a k2benchmark.txt
51f1ce428a9a07d7b7b394f9c8302279 kernel/asm/kernToUser.s
d1d5fe7833e97870de0e1539f8581727 kernel/asm/startup.s
dc310ba0937f8818a8735c4fed086051 kernel/asm/trap.s
770dc066a65a334181fb303745f14dad kernel/include/labenv/timer.c
a5d669bd2921cb530cd57401cf86af26 kernel/include/labenv/timer.h
38cfc8c969ea2246fc27635304fd1947 kernel/include/labenv/ts7200.h
ee90c5ee9fadbe5f7cf574db5241d256 kernel/include/versatilepb/timer.c
4cd17ccd0c85a77c30bb7df4ead73ae7 kernel/include/versatilepb/timer.h
3eee261c61989efe86d9a2f1ebe11638 kernel/include/versatilepb/versatilepb.h
99df351d9e5ab9ece03655fe6145919c kernel/src/cp_vec.c
503fb56ff1929bcc8d7a6b3d19b2524e kernel/src/cp_vec.h
31f8a414fa662b4739b2d868a6fffd9 kernel/src/events.c
ba6a3c142b44633cc80c765f36939f62 kernel/src/events.h
1ea998c1c4c00a59cf4c2134a159dc78 kernel/src/handle_abort.c
b84f77628074c219bdf86a19907f4fed kernel/src/iio.c
580fbeb1bc250578424ff209253649fa kernel/src/iio.h
07b8601fe7f1dbfb85e55a311a0bf890 kernel/src/interrupt.c
f105abe4e0d376eb9a0e700e20a9e626 kernel/src/interrupt.h
a0946900f956766d853fa86ea49f1628 kernel/src/kassert.c
8baadeeeeb32c820cce4b6420efcb92b kernel/src/kassert.h
c7f303448c61cd0b620060ef10915cb8 kernel/src/kusage_stats.c
c1ed6afa70cb921f87c0e90770edb87b kernel/src/kusage_stats.h
56ff6f6f508b29ede42e0cf2831ca2c7 kernel/src/multitasking/messaging.c
8da39e0fbf99d840a126cad76ea4ed57 kernel/src/multitasking/messaging.h
d8f5950a0cac94759ad5200fb735ddd1 kernel/src/multitasking/ready_queue.c
acdaabac90092feb2d815d93daa6c160 kernel/src/multitasking/ready_queue.h
149c5145f09e141dd7a5c68ba1bd3c2f kernel/src/multitasking/schedule.c
```

a11a9befd765f6c6c048f6b84860d0f9	kernel/src/multitasking/schedule.h
5864d87dbe1c10fd564ccd73a3b06a6d	kernel/src/multitasking/scheduler.c
2a6005ff964276bd1f83ba93f2e06b86	kernel/src/multitasking/scheduler.h
1ff609f65cd9531a647ce6575c039b6f	kernel/src/multitasking/send_queue.c
d2fd55f45ab57e8e5c75a5a072bb74ec	kernel/src/multitasking/send_queue.h
920cbd04b31f243120179cc369514d87	kernel/src/multitasking/task.c
b20b570ef1305a2e44efb45b8919064f	kernel/src/multitasking/task.h
4ad860fd0d43e6a9cf29eacf89e2b06d	kernel/src/queue.h
2ec64436601dc9e2e897f998fc67a9dd	kernel/src/syscall/syscall.c
0d26653864f2251c8a286335fc5d4c2a	kernel/src/syscall/syscall.h
64661f8128c9d1edfd59240e625a414c	kernel/src/vic.c
61bf440b522595f947ffc92a4aa30bcb	kernel/src/vic.h
910ddd9774bc89c04f804f76669354ce	lib/a0codes.h
bec5edf5b40af4209c289f8c83f248ef	lib/attributes.h
59506a2fc8c1e78f1287e2d9eb454b34	lib/benchmark.c
3b7d15e91a197c4a1a4cdfbe674f88b1	lib/benchmark.h
ec862c22bb31b480dce098dda7c8899f	lib/buffer.h
7949f4bf8c52321c0bcf49e3b67817ff	lib/buffertypes/char_buffer.c
4ca46294d99b93f653cbe9c850362146	lib/buffertypes/char_buffer.h
0dd2910bf5314d67758f17c17ef855ee	lib/buffertypes/int32_t_buffer.c
5f0d55eeb4a647b2929700f046d402d7	lib/buffertypes/int32_t_buffer.h
330169419f4b7705cbb42cd773b1547c	lib/codes.c
dbcecff713b5e55b43f3a44db4d006a7	lib/codes.h
d41d8cd98f00b204e9800998ecf8427e	lib/constants.c
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dd7ed407227be8ff5e72530a2e86ada4	lib/event_data.h
b15b48f8259ac50456d9156bef498f60	lib/messages.h
f16c0325983ba4883ecf69748fb865e3	lib/priority_queue.h
ff8862852668a149f4a2d8cf8a3d741d	lib/terminal.h
af9cdf9014bec08c6df74cead3ca105d	lib/track/README.txt
24bb477557f6df611901467842ff7286	lib/track/model.c
f52586fee7643827909bc1cf5a284296	lib/track/model.h
cdc0890b052aefe296680600c99cb346	lib/track/model_data.h
7707b57cb3a6c3703c0e3da3acbef763	lib/track/parse_track.py
1e06c8505279ed9f4d10136465c81618	lib/track/parts_tracka
a408ef1736b356024bf0dc2bc05d98b0	lib/track/parts_trackb
5b39cb2220118c495cda21b122a8fc57	lib/track/track_data.c
796b6b9fd364e935a86ce044c38985d5	lib/track/track_data.h
75c334f0e9006d4eaf43c60ebd3a14eb	lib/track/track_node.h
50e0b1150b39a2425cb2180c33e0e57f	lib/track/tracka
dab2764f1d7f07aa454bad2ec01158b8	lib/track/trackb
90572a2b6c9203c958dac2978dd2b3e5	lib/track/tracks.c
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2d81bda8e6453ea87e964edefb8d37c5	reports/k1.pdf
3c476edf2886bdb295d9f5e37a748d9c	reports/k2.pdf

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c1e9354e62486019325b3d7e096f17b4 test-resources/assert.h
b1a7d80ccd36efa7b4db75a7a6a9195a test/Makefile
d41d8cd98f00b204e9800998ecf8427e test/e2e/__init__.py
5e5251a0b50afa28bf4b46424a6b3d26 test/e2e/qemu_tcp_wrapper.py
f1e50c9027d900c43570595e642fd518 test/e2e/snapshots/k2.txt
57e0cf79450fa3e8dc465928d0e82668 test/e2e/snapshots/k3.txt
2135a39d326e969a7a1aff8ed796464c test/e2e/snapshots/printf_happy_path.txt
5c894b95e44a5b8d0e850fc07fa45f93 test/e2e/test_clock.py
69151d4fe73f8908dffe4f4358986f6c test/e2e/test_commandparsing.py
1b2357ce0443c4771348ecf34ffefb29 test/e2e/test_destroy.py
8f749bae092472967cd325ee379e4d03 test/e2e/test_getcputc.py
bf210ede7d676c369e780b20587c3f5b test/e2e/test_interrupts.py
939ce9936dc62dba256a3a3b18f4ecd2 test/e2e/test_kernel_demo.py
207f9c96a203fb1408236396eb8c4da1 test/e2e/test_messaging.py
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b137b49b04d3fd3a55f7aa94d500f799 test/e2e/test_nameserver.py
705f20c8af9c2bb6be26efcab7a8caac test/e2e/test_printf.py
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30e544606327baabd6afe99c229faf9f test/e2e/test_test.py
3834f5e022525034f78b19b6d5b764fa test/unit/test_all.cc
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916f5fab4c3bf56c62b8588863c9cd76 test/unit/test_buffer.cc
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1909548396588628d189701a805e7bb4 test/unit/test_ready_queue.cc
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ee004b6ffd40e6513204bdd28474af7f test/unit/test_scheduler.cc
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36889e34775aefba76462f7ede00349b test/unit/test_task.h
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c1a84bc2d0e1e77eda929b31f622dfb5 usr/idle.c
0850a1ff169d4bf316f23f252bd1a1a2 usr/idle.h
e8ca8a6998df91215838705f41662823 usr/ioserver.c
b36ecdff097fc6d11a72b09a64bcae6a usr/ioserver.h

686bfad6b5f7a70f10865e0bc29a5249	usr/k1.c
758b67d7c795e165ba195c0d39d6bbe0	usr/k1.h
b8923150be8054c9bfa75bd511f9bc21	usr/k2.c
c383d0978426f930db936eb03b5090ef	usr/k2.h
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87e3b6299a0d9261e6a0a3dc7a0adaa2	usr/k3.h
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836be31c955cd68fb41d2fc263cadab7	usr/lib/clock_wait_queue.h
e2d4643a2b52bbcf79f4a4a94b86a598	usr/lib/global_track_state.c
cde4e70f68f7f9a395d220f9fb9dc307	usr/lib/global_track_state.h
0186cd2be5fe906309783bcef070b5c8	usr/lib/search_node_queue.c
605036af1536d568a4dc2f9727bdb31e	usr/lib/search_node_queue.h
f23ab005de96d571487ac46cd51672cd	usr/nameserver.c
b943c7708fafeb759a3ddc25706848e8	usr/nameserver.h
d76670df6cf30ef0ed1fe8a365082522	usr/notifier.c
a266f655714bf034e10ee80066a04045	usr/notifier.h
fcc1afd945289c117d94790a3991141a	usr/project.c
5733193ca6fb94b9928aaa311522a163	usr/project.h
7c3d3b1b7553e85b5ac5c952b19eb0f2	usr/spam.c
c6b26aad9c868a310e2a61543f1b6d54	usr/spam.h
c76fea6b27a5e29f1f61097ac827164b	usr/test/awaitevent/test_rx_terminal.c
987024da0946d3bc51fa9b517aba1e4d	usr/test/awaitevent/test_rx_terminal.h
324862e41991fa243099d43763f7d490	usr/test/awaitevent/test_timer_interrupt.c
fd0230e03c6329d23cd59ce714d14841	usr/test/awaitevent/test_timer_interrupt.h
7609b1ef434e30e5c7d49477fb636423	usr/test/awaitevent/test_tx_terminal.c
c4db6de70684fda79da761d55c674458	usr/test/awaitevent/test_tx_terminal.h
31041ff5a0154e679718472f2cd150eb	usr/test/clock/clock_util.c
74a779c5688003aa346dc6d18d84a2d4	usr/test/clock/test_clock.h
4df05ca408a98b04ecb8e5a4647342ec	usr/test/clock/test_clock_accuracy.c
7b58840919f048032eab36dcaec632bf	usr/test/clock/test_clock_errors.c
7e5373809fd8b91e2c3aa4dee4872665	usr/test/clock/test_clock_syscall_accuracy.c
bed867b2ad5bb4aae38a223eb2a750ba	usr/test/clock/test_clock_syscall_errors.c
ca831d5b374cae3c232f46f5a620e730	usr/test/destroy/test_destroy.h
7145bd0c23a6ccc35d7b9bee765fda4e	usr/test/destroy/test_destroy_block_kill.c
c57a920919fb3190f13de17219e6aca8	usr/test/destroy/test_destroy_many_tasks.c
0493f74de96ce23b3cfd6a978ed14722	usr/test/destroy/test_destroy_nameserver.c
0a92605d5d76da9cd664f3106f9a6058	usr/test/destroy/test_destroy_parent_tid.c
ae156df9cd60b84db962141ae273c743	usr/test/destroy/test_destroy_send_queue.c
4cfba04d3a6dc896ae6c9f6730ba34cd	usr/test/destroy/test_destroy_task_limit.c
1377b67b1599f9e97f783013fecc80cc	usr/test/iio/test_getcputc_errors.c
606ca77a18d32ae87856761098065e97	usr/test/iio/test_getcputc_errors.h
96b46eae0fce398869696ba43e175bf2	usr/test/iio/test_getcputc_happypath.c
943f5683a7afd3a053e5a864aa586a35	usr/test/iio/test_getcputc_happypath.h
091124f3277913c6339829b031478ea7	usr/test/iio/test_printf.c
93d9372b059af217848ce09cf45e69c4	usr/test/iio/test_printf.h
661a668400e184f442e4a9110730ba29	usr/test/messaging/test_messaging.h
d262f35cce581eda07aff2484fd2d8b5	usr/test/messaging/test_messaging_basic.c
4e0595b514cecd036282b86b0d1ddc02	usr/test/messaging/test_messaging_exit_with_blocked.c
497af6748eae1fdaf6a437d80dcce337	usr/test/messaging/test_messaging_fifo_send.c
f0abb91510a1c1433da5977ba2a1881d	usr/test/messaging/test_messaging_invalid_tid.c
6ac01327ddbffa06649f0c20ed04e8ec	usr/test/messaging/test_messaging_receive_before_send.c
76583e962409b9a90c62df1e97b74598	usr/test/messaging/test_messaging_reply_target_zombie.c
47c902d889407fee469b052bec91585c	usr/test/messaging/test_messaging_same_priority.c
a17bf4e6f1b05c814f24c35fe3cd5677	usr/test/messaging/test_messaging_send_recipient_zombie.c
c85eef4e381e81e765ec21f4154f21d3	usr/test/messaging/test_messaging_sequence.c
7b973bb3f9a91d9cd292229d0c90f11d	usr/test/messaging/test_messaging_tree.c
8bd72ff578d51d007fe156e698e1b48c	usr/test/messaging/test_messaging_truncation.c
b7f826a49bea1adb7411f4a567a32da5	usr/test/model/test_constant_velocity_model.c

162edac2d7754334f816be6c22a56c32
7b12b02c33d12bbf7b78a152d3b4f533
7dc17c7a46e288536c3ea61c03fb0be0
dde567ac51c2941dbc500461d145829a
02235009ba1e99236fe1fbc988037ee9
7101f020db73ffcf486747bebc6150b
7e087751d128cd0916702f843843f3d0
2d3f90279df9fe86d7b8241d0e2f7a15
9ae182d2a7d7d6a327d70d6593eea0de
fbb92e62ce4cdab26d53efd17ac977c5
90a28211c3a519e8eb53142e3443de96
97e4576bd06081ac956acb15838a51f6
0e290966f99895d1a336e40a7857b5bb
6abf2e4dd54a933308ee396f78e0ef2d
1984c9c84e244d37c2356ce4b849ad59
9f14c14716882e04d47d0b79acf46d1e
78f66d0bc873a3fa360216572112cc40
14b7ce3a2565137c4af812890ead56de
d5dbea238e2f485cd1bf36fb486095c7
17b755c38554a89b40173233565c59b5
094b0af1d908d2e315ec109209971614
9a5ffa058f7ae4b1e1fc4f71d3e7818b
eaae63d1c25a445c22383bd71612ec55
e2df5bda86c4ca88b09e453e5b029e7c
9bb78849ac1ec21fc38393cf5f65a1a3
66d7c115ce8fe1f138a7da2a9798235f
a8e19df150c1fa62d1f8b68cd13ea758
109f0d4968b39ef3cfff5e0559a91eb71
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f1799d532f8869a97c6accf25ec2b07a
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83053e202339e79cbc203b0570f028a5
68cb6a79094d8d27d2bcd50df9ed003b
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1d722b33a2664e55f31e72b04b780e51
c6ffd8a34444416c0b5bbe0d625d330b
1cded7ce548c611e9bc86595c53235c0
aff38ab9ff0cb570e25fb82b98e49373
1cba68969193e3c7b803f22069e0552c
5ff784f52925c03dc59302ce3f3ea3c1
21dc5c3a3827b0a1c129a217a6d3037d
2c01d6aaa47526e43c2d5984068ed6c0
884c7eea94da47a2b2077864390e7e59
45b7e0f0c796b0aebcab4c6fef2b48a3
6af3eb53e40f69937af4200b01e61688
d4a5df8b7e670131ff68b6b54ae7fb4f
0a0b7d348dec1eaa720eab6bbb3b9fb
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df30bc35ca8683edc4fa5790440d8fc0
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1a63accf05f4a4f7624a088732419811
d4cde46f9f57f428979a2c01e07e4fe6
331a7cb4f8893461a02679504c9c25f2
62e96a337cd8f2496d72a34f5f7b2043
6e1c198a8a9e0570f1fa3ef71a105f0c
usr/test/model/test_distance_between_sensors.c
usr/test/model/test_model.h
usr/test/model/test_sensors_are_paired.c
usr/test/model/test_stopping_distance_model.c
usr/test/model/test_stopping_time_model.c
usr/test/nameserver/ns_tid.c
usr/test/nameserver/ns_tid.h
usr/test/nameserver/test_nameserver_happypath.c
usr/test/nameserver/test_nameserver_happypath.h
usr/test/nameserver/test_nameserver_too_many.c
usr/test/nameserver/test_nameserver_too_many.h
usr/test/nameserver/test_nameserver_wrapper_errors.c
usr/test/nameserver/test_nameserver_wrapper_errors.h
usr/test/route_execution/test_route_execution.c
usr/test/route_execution/test_route_execution.h
usr/test/router/test_router.c
usr/test/router/test_router.h
usr/test/router/test_router_basic.c
usr/test/router/test_router_complete.c
usr/test/router/test_router_reversals.c
usr/test/router/test_router_same_sensor.c
usr/test/router/test_router_sensor_pair.c
usr/test/servers/test_track_reservation_server.c
usr/test/servers/test_track_reservation_server.h
usr/test/servers/test_train_coordinates_server.c
usr/test/servers/test_train_coordinates_server.h
usr/test/test_message_benchmark.c
usr/test/test_message_benchmark.h
usr/test/test_mypriority.c
usr/test/test_mypriority.h
usr/test/test_runner.c
usr/test/test_runner.h
usr/test/test_undefined_handler.c
usr/test/test_undefined_handler.h
usr/train/calibration/acceleration_calibrator.c
usr/train/calibration/acceleration_calibrator.h
usr/train/calibration/stopping_distance_calibrator.c
usr/train/calibration/stopping_distance_calibrator.h
usr/train/calibration/velocity_calibrator.c
usr/train/calibration/velocity_calibrator.h
usr/train/commands.c
usr/train/commands.h
usr/train/parameters.c
usr/train/parameters.h
usr/train/prediction.c
usr/train/prediction.h
usr/train/reverser.c
usr/train/reverser.h
usr/train/router.c
usr/train/router.h
usr/train/sensors/sensor_interpreter.c
usr/train/sensors/sensor_interpreter.h
usr/train/sensors/sensor_secretary.c
usr/train/sensors/sensor_secretary.h
usr/train/switcher.c
usr/train/switcher.h
usr/train/track_reservation_server.c
usr/train/track_reservation_server.h

0f7041a78a79637b5cb92df9ba1df9b6	usr/train/track_state_controller.c
0e08b6ee35eb03666ce1bb5b8e343ae4	usr/train/track_state_controller.h
ed33cbfba43f0bfc42854e4373edcffa	usr/train/train_conductor.c
e6ae489e9c5bdb23d9b4ac002f057973	usr/train/train_conductor.h
e123f29ab0026ed4627ea5da7a2e79b1	usr/train/train_coordinates_server.c
38532351ddc418b1954307ca50cb0251	usr/train/train_coordinates_server.h
489b77aba5e80b86f2b3fe1a17f4d622	usr/train/train_util.c
4dfddc7c12e53fc4ecb946a33d23d619	usr/train/train_util.h
d5881d3437ddfce89545e333ca545c04	usr/train/turnout_resetter.c
b2edaf6afa9268eb4e8b30c435f06f9b	usr/train/turnout_resetter.h
6cae62c97dc3e1b1de204974a295e55a	usr/user_data_abort.h
45499fb865c9b64dfaf169deb0522088	usr/views/clock_view.c
3ffdc9be852e4ad6ef8064d500fbb8da	usr/views/clock_view.h
68a12eeef2bc46b909d291586161f41b	usr/views/sensor_view.c
a17a17ab1f35fcad994faa3b8e416a37	usr/views/sensor_view.h
95f3ef64a7ba072541ff321064db1234	usr/views/train_location_view.c
2e987819156f5206de90c7f34b55d2f2	usr/views/train_location_view.h
3ea97403bbeab21a28a11217d31c8754	usr/views/turnout_view.c
f14ac6112e4e42db3cd24a298a6d5cb4	usr/views/turnout_view.h
a7668b81a997cb9d602415320f5d33f3	versatilepb.ld
3f052cb7f6b25c5e80dca05f284701d3	versatilepb_e2e.ld
c06605bea54e7505a4ceadee05e53a6a	versatilepb_e2e_iio.ld
89441cccfbea450f485e451770d95f95	versatilepb_e2e_iiotmr.ld
03a9a6a402360d35fe9d1aedfd8e98e7	versatilepb_e2e_tmr.ld

5.b Reservations

The last commit on the branch `reservation-based-route-execution` has SHA `c9e8aef8cdc0984f0fb678c9f4b27883`.

5.b.1 MD5 hashes

```
git ls-files | grep -v 'test/googletest' | xargs md5sum
a5ab21bd63e960032282b0c6006de5cc .gitignore
4bbdec35a4b9dc9ca8615b1e321de502 .gitmodules
58bb9fbcf62dc59a35491ac53f0b612a .travis.yml
cdbc7f7beb502f2adcba5aeb12b7e8e8c Doxyfile
47ca7bed356151e059397cc12eac5347 Makefile
72528caa4dc861d6f0f2590e0aac6000 PULL_REQUEST_TEMPLATE.md
db17664126ec304585d152833b41ab72 README.md
ffffb471c0ef031de7290e9803a651aac gcc-ld
d7810fab7487fb0aad327b76f1be7cd7 gcc-ldCOPYING
10b31708f10ca2e4a77d04495578cb8b include/bwio.c
1506ac36c03fc3c02a62124aec4dbf20 include/bwio.h
1e06c47ed88775686330932eb570b056 include/io.h
28fb38ae413a58784deb9e362e2e56d0 include/myio.c
93cdb176a9db6bf6073d3f9ec5996df7 include/myio.h
0ff6bee28590e1b949a208361291deab include/mytimer.c
8958f41681273f9891540bc5289bb6e4 include/mytimer.h
9e66057d63ac6141d27d3f7d627298b8 include/rawio.c
2314714decf98c1fde63b96f2ffaf2ab include/rawio.h
a51b441bd12f84e40333d2dfde291780 include/timer_data.h
74c63a11fc85af6c146dbcb5fa19b14a k2benchmark.txt
51f1ce428a9a07d7b7b394f9c8302279 kernel/asm/kernToUser.s
d1d5fe7833e97870de0e1539f8581727 kernel/asm/startup.s
dc310ba0937f8818a8735c4fed086051 kernel/asm/trap.s
770dc066a65a334181fb303745f14dad kernel/include/labenv/timer.c
a5d669bd2921cb530cd57401cf86af26 kernel/include/labenv/timer.h
38cfc8c969ea2246fc27635304fd1947 kernel/include/labenv/ts7200.h
ee90c5ee9fadbe5f7cf574db5241d256 kernel/include/versatilepb/timer.c
4cd17ccd0c85a77c30bb7df4ead73ae7 kernel/include/versatilepb/timer.h
3eee261c61989efe86d9a2f1ebe11638 kernel/include/versatilepb/versatilepb.h
99df351d9e5ab9ece03655fe6145919c kernel/src/cp_vec.c
503fb56ff1929bcc8d7a6b3d19b2524e kernel/src/cp_vec.h
31f8a414fa662b4739b2d868a6ffffda9 kernel/src/events.c
ba6a3c142b44633cc80c765f36939f62 kernel/src/events.h
1ea998c1c4c00a59cf4c2134a159dc78 kernel/src/handle_abort.c
b84f77628074c219bdf86a19907f4fed kernel/src/iio.c
580fbeb1bc250578424ff209253649fa kernel/src/iio.h
07b8601fe7f1dbfb85e55a311a0bf890 kernel/src/interrupt.c
f105abe4e0d376eb9a0e700e20a9e626 kernel/src/interrupt.h
a0946900f956766d853fa86ea49f1628 kernel/src/kassert.c
8baadeeeeb32c820cce4b6420efcb92b kernel/src/kassert.h
c7f303448c61cd0b620060ef10915cb8 kernel/src/kusage_stats.c
c1ed6afa70cb921f87c0e90770edb87b kernel/src/kusage_stats.h
56ff6f6f508b29ede42e0cf2831ca2c7 kernel/src/multitasking/messaging.c
8da39e0fbf99d840a126cad76ea4ed57 kernel/src/multitasking/messaging.h
d8f5950a0cac94759ad5200fb735ddd1 kernel/src/multitasking/ready_queue.c
acdaabac90092feb2d815d93daa6c160 kernel/src/multitasking/ready_queue.h
149c5145f09e141dd7a5c68ba1bd3c2f kernel/src/multitasking/schedule.c
a11a9befd765f6c6c048f6b84860d0f9 kernel/src/multitasking/schedule.h
5864d87dbe1c10fd564ccd73a3b06a6d kernel/src/multitasking/scheduler.c
2a6005ff964276bd1f83ba93f2e06b86 kernel/src/multitasking/scheduler.h
```

1ff609f65cd9531a647ce6575c039b6f	kernel/src/multitasking/send_queue.c
d2fd55f45ab57e8e5c75a5a072bb74ec	kernel/src/multitasking/send_queue.h
920cbd04b31f243120179cc369514d87	kernel/src/multitasking/task.c
b20b570ef1305a2e44efb45b8919064f	kernel/src/multitasking/task.h
4ad860fd0d43e6a9cf29eacf89e2b06d	kernel/src/queue.h
2ec64436601dc9e2e897f998fc67a9dd	kernel/src/syscall/syscall.c
0d26653864f2251c8a286335fc5d4c2a	kernel/src/syscall/syscall.h
64661f8128c9d1edfd59240e625a414c	kernel/src/vic.c
61bf440b522595f947ffc92a4aa30bcb	kernel/src/vic.h
910ddd9774bc89c04f804f76669354ce	lib/a0codes.h
bec5edf5b40af4209c289f8c83f248ef	lib/attributes.h
59506a2fc8c1e78f1287e2d9eb454b34	lib/benchmark.c
3b7d15e91a197c4a1a4cdfbe674f88b1	lib/benchmark.h
ec862c22bb31b480dce098dda7c8899f	lib/buffer.h
7949f4bf8c52321c0bcf49e3b67817ff	lib/buffertypes/char_buffer.c
4ca46294d99b93f653cbe9c850362146	lib/buffertypes/char_buffer.h
0dd2910bf5314d67758f17c17ef855ee	lib/buffertypes/int32_t_buffer.c
5f0d55eeb4a647b2929700f046d402d7	lib/buffertypes/int32_t_buffer.h
330169419f4b7705cbb42cd773b1547c	lib/codes.c
dbcecff713b5e55b43f3a44db4d006a7	lib/codes.h
d41d8cd98f00b204e9800998ecf8427e	lib/constants.c
06e84818bb23369072347e52dc27ab46	lib/constants.h
38424f2856725ba4ce4919eefe5e3142	lib/crash.h
608c3732de6719e206bf1c76772bd549	lib/crash.s
dd7ed407227be8ff5e72530a2e86ada4	lib/event_data.h
fae80e64ce25cf9974620841292749e4	lib/messages.h
f16c0325983ba4883ecf69748fb865e3	lib/priority_queue.h
69d43a1b0cc8c8a51dd10dcfc8cd09d9	lib/terminal.h
af9cdf9014bec08c6df74cead3ca105d	lib/track/README.txt
24bb477557f6df611901467842ff7286	lib/track/model.c
f52586fee7643827909bc1cf5a284296	lib/track/model.h
cdc0890b052aefe296680600c99cb346	lib/track/model_data.h
7707b57cb3a6c3703c0e3da3acbef763	lib/track/parse_track.py
1e06c8505279ed9f4d10136465c81618	lib/track/parts_tracka
a408ef1736b356024bf0dc2bc05d98b0	lib/track/parts_trackb
ab1c3a98d024260d9f7f5ae1c362072f	lib/track/track_data.c
7c184c0a4da0625e6181c2cbff3cecdc	lib/track/track_data.h
fe1470efa598d5daf6f8d6aefd723bed	lib/track/track_node.h
50e0b1150b39a2425cb2180c33e0e57f	lib/track/tracka
dab2764f1d7f07aa454bad2ec01158b8	lib/track/trackb
90572a2b6c9203c958dac2978dd2b3e5	lib/track/tracks.c
84244d5defb8528197eff11a8a3b21ee	lib/track/tracks.h
91ed3e04dd950a7dc99259e6fe2d0d5c	lib/tststdlib.c
8e768a4e0cc06e3f9a8e8827777e06d	lib/tststdlib.h
e80f2789ca24d327bac466b79ccc5290	lib/tstring.c
2a7117fdcad90f1e3029ad923292f15	lib/tstring.h
06e369b76c2d125b61ac6a95d7d31309	lib/usage_stats.c
2c7495e2cf58fe43659b7ac7fed0b7ee	lib/usage_stats.h
e4eb310dce47b65766735c6be662ca28	lib/user_command.c
1ed607899f1e2ee68c2a0aa57899a8d2	lib/user_command.h
e377e05740f18eef528361f788f1c7f8	main.c
04a99fa4e57230b2b2b7a525a1105097	main.ld
d9cd792c1413ac79bf45f799ae903f42	reports/a0-csulshoe.pdf
2d81bda8e6453ea87e964edefb8d37c5	reports/k1.pdf
3c476edf2886bdb295d9f5e37a748d9c	reports/k2.pdf
e962ebaab43701b2baa697adfbe05f7d	reports/k3.pdf
4569f774527daad1d1c706f112f26701	reports/k4.pdf
caec5627ce3fd40404d86e59d23f9578	reports/t1.pdf

```

19726b3f18ad8104d219139cf8f4dec6 scripts/parse_calib_log.py
7c70fec0ceecb03f5246ce63d01cbf9e scripts/train_data_analysis.ipynb
1c7a429e1ced54dbb23098d3078a30e8 stats.md
da4d2d5a9d3d7971c83928f051ef6b58 test-resources/assert.c
c1e9354e62486019325b3d7e096f17b4 test-resources/assert.h
b1a7d80ccd36efa7b4db75a7a6a9195a test/Makefile
d41d8cd98f00b204e9800998ecf8427e test/e2e/__init__.py
5e5251a0b50afa28bf4b46424a6b3d26 test/e2e/qemu_tcp_wrapper.py
f1e50c9027d900c43570595e642fd518 test/e2e/snapshots/k2.txt
57e0cf79450fa3e8dc465928d0e82668 test/e2e/snapshots/k3.txt
2135a39d326e969a7a1aff8ed796464c test/e2e/snapshots/printf_happy_path.txt
5c894b95e44a5b8d0e850fc07fa45f93 test/e2e/test_clock.py
6964a7e449b707acdd7ac63b5c2b89b6 test/e2e/test_commandparsing.py
1b2357ce0443c4771348ecf34ffefb29 test/e2e/test_destroy.py
8f749bae092472967cd325ee379e4d03 test/e2e/test_getcputc.py
bf210ede7d676c369e780b20587c3f5b test/e2e/test_interrupts.py
939ce9936dc62dba256a3a3b18f4ecd2 test/e2e/test_kernel_demo.py
207f9c96a203fb1408236396eb8c4da1 test/e2e/test_messaging.py
259c44b5ce5ce6016a857ac724f1dd4f test/e2e/test_model.py
63428d6fbf558a456bfd1503dbffb217 test/e2e/test_mypriority.py
b137b49b04d3fd3a55f7aa94d500f799 test/e2e/test_nameserver.py
705f20c8af9c2bb6be26efcab7a8caac test/e2e/test_printf.py
e8fcdd41235268e20a8b4ce8ff2ac0a9 test/e2e/test_router.py
f7c6f842ecb68d41b2167ad29552b783 test/e2e/test_segfaults.py
40ac38c0dddc0f7411311cf6edf7e455 test/e2e/test_servers.py
30e544606327baabd6afe99c229faf9f test/e2e/test_test.py
3834f5e022525034f78b19b6d5b764fa test/unit/test_all.cc
65a92d844a6d98056dff9024003fbfc test/unit/test_all.h
916f5fab4c3bf56c62b8588863c9cd76 test/unit/test_buffer.cc
097d11f425ed7b415cba26be7efbc158 test/unit/test_buffer.h
5fb6e05d355b3e0750cfc5c0207eb80f test/unit/test_clock_wait_queue.cc
825a054548d34057930fc5cbea517933 test/unit/test_clock_wait_queue.h
be7726ba1a922ec5ab26525114d7704d test/unit/test_messaging.cc
f34aa46731d487e48a5cd1a9a681b518 test/unit/test_messaging.h
1909548396588628d189701a805e7bb4 test/unit/test_ready_queue.cc
917d4146f8727af1b9986cd4b94565a3 test/unit/test_ready_queue.h
ee004b6ffd40e6513204bdd28474af7f test/unit/test_scheduler.cc
c31f7630705c36d377356eace6e86c9b test/unit/test_scheduler.h
ebf57a23d6c248f7de1547e67b2900c7 test/unit/test_stdlib.cc
664c5ed933718c9c833e37a4663e6ef4 test/unit/test_stdlib.h
feb2d463f057a6d3b342f467e7682ce2 test/unit/test_task.cc
36889e34775aefba76462f7ede00349b test/unit/test_task.h
a0addff42ca5648e4f3563213bdd0f4b test/unit/test_track.cc
e5df1a95f1a92008e9c7c15465284f00 test/unit/test_track.h
959525c7d2ffd289107d3f092a5bd1ea test/unit/test_track_data.cc
b4300d87e1872fa230f6ff9e73a4de23 test/unit/test_track_data.h
0412ad5d98215489d254beeca159caf8 usr/clock.c
b4566bc63807ef8e5e47e70ae6140774 usr/clock.h
34adafac971eb707fd3daeb810254df9 usr/command_dispatcher.c
9e898711ebf6c9e5de7e2a7afbf6d004 usr/command_dispatcher.h
c1a84bc2d0e1e77eda929b31f622dfb5 usr/idle.c
0850a1ff169d4bf316f23f252bd1a1a2 usr/idle.h
e8ca8a6998df91215838705f41662823 usr/ioserver.c
b36ecdff097fc6d11a72b09a64bcae6a usr/ioserver.h
686bfad6b5f7a70f10865e0bc29a5249 usr/k1.c
758b67d7c795e165ba195c0d39d6bbe0 usr/k1.h
b8923150be8054c9bfa75bd511f9bc21 usr/k2.c
c383d0978426f930db936eb03b5090ef usr/k2.h

```

3efb1e872f6ea02246e5d87f3fccce8c	usr/k3.c
87e3b6299a0d9261e6a0a3dc7a0adaa2	usr/k3.h
3f9b92e877e51c8a6556121920a974e6	usr/lib/clock_wait_queue.c
836be31c955cd68fb41d2fc263cadab7	usr/lib/clock_wait_queue.h
e2d4643a2b52bbcf79f4a4a94b86a598	usr/lib/global_track_state.c
cde4e70f68f7f9a395d220f9fb9dc307	usr/lib/global_track_state.h
0186cd2be5fe906309783bcef070b5c8	usr/lib/search_node_queue.c
605036af1536d568a4dc2f9727bdb31e	usr/lib/search_node_queue.h
f23ab005de96d571487ac46cd51672cd	usr/nameserver.c
b943c7708fafef759a3ddc25706848e8	usr/nameserver.h
d76670df6cf30ef0ed1fe8a365082522	usr/notifier.c
a266f655714bf034e10ee80066a04045	usr/notifier.h
fdfa69649f925187a96308a0a05c7f0d	usr/project.c
3c4dabb4eeb5fe68ab54fecc40812be5	usr/project.h
7c3d3b1b7553e85b5ac5c952b19eb0f2	usr/spam.c
c6b26aad9c868a310e2a61543f1b6d54	usr/spam.h
c76fea6b27a5e29f1f61097ac827164b	usr/test/awaitevent/test_rx_terminal.c
987024da0946d3bc51fa9b517aba1e4d	usr/test/awaitevent/test_rx_terminal.h
324862e41991fa243099d43763f7d490	usr/test/awaitevent/test_timer_interrupt.c
fd0230e03c6329d23cd59ce714d14841	usr/test/awaitevent/test_timer_interrupt.h
7609b1ef434e30e5c7d49477fb636423	usr/test/awaitevent/test_tx_terminal.c
c4db6de70684fda79da761d55c674458	usr/test/awaitevent/test_tx_terminal.h
31041ff5a0154e679718472f2cd150eb	usr/test/clock/clock_util.c
74a779c5688003aa346dc6d18d84a2d4	usr/test/clock/test_clock.h
4df05ca408a98b04ecb8e5a4647342ec	usr/test/clock/test_clock_accuracy.c
7b58840919f048032eab36dcaec632bf	usr/test/clock/test_clock_errors.c
7e5373809fd8b91e2c3aa4dee4872665	usr/test/clock/test_clock_syscall_accuracy.c
bed867b2ad5bb4aae38a223eb2a750ba	usr/test/clock/test_clock_syscall_errors.c
ca831d5b374cae3c232f46f5a620e730	usr/test/destroy/test_destroy.h
7145bd0c23a6ccc35d7b9bee765fda4e	usr/test/destroy/test_destroy_block_kill.c
c57a920919fb3190f13de17219e6aca8	usr/test/destroy/test_destroy_many_tasks.c
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 usr/train/train_coordinates_server.c

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