CastorOne: World's Largest Pipelay Vessel
The Planning System

made by

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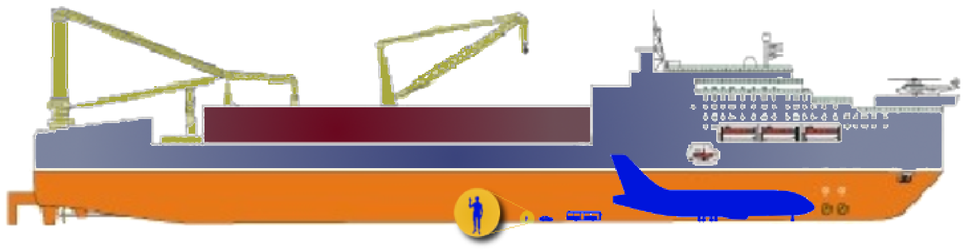
THE VESSEL: CASTOR ONE

Castor One targets the large gas trunklines and oil export pipelines, in difficult environments, deepwater and arctic conditions

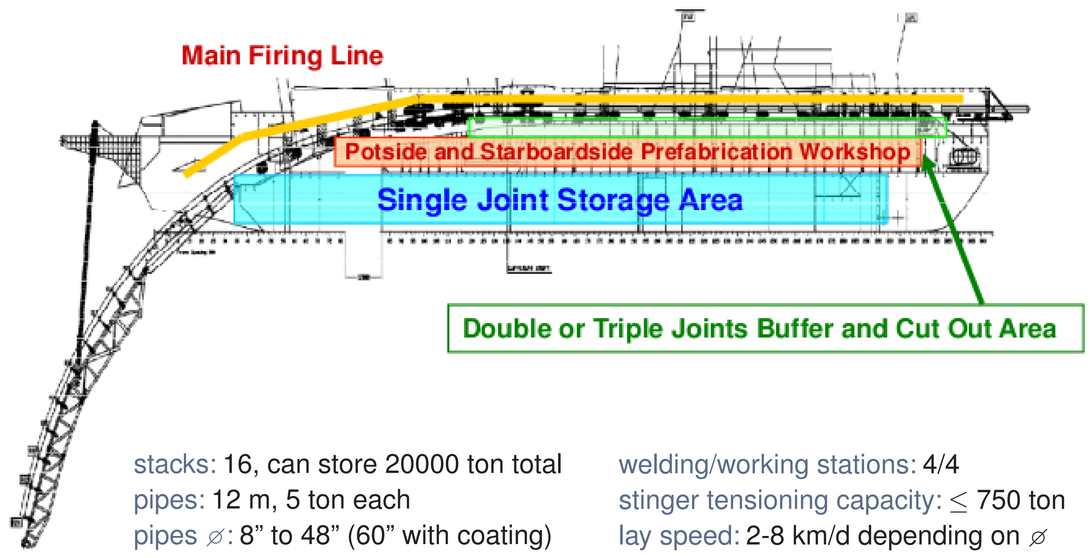
Main particulars



constructor: ENI/Saipem
construction year: 2012
L/W/H: 330 m / 40 m / 67 m
displacement: 100000 ton
max speed: 14 knots (26 km/h)
accommodation: 702 persons

main gensets: 8 x 8,400 kW at 600 rpm each
emergency generator: 1 x 1,200 kW
power distribution: 2 switchboards 11 kV
bow tunnel/azimutal thrusters: 2 x 35 t / 6 x 92 t
main shafts: 2 x 8,000 kW

Pipe Storage and Production Capacity



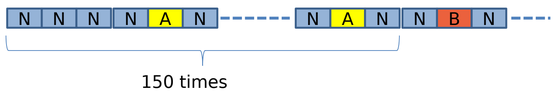
stacks: 16, can store 20000 ton total
pipes: 12 m, 5 ton each
pipes ⌀: 8" to 48" (60" with coating)
cranes: 2 x 55 t @ 35 m

welding/working stations: 4/4
stinger tensioning capacity: $\leq$ 750 ton
lay speed: 2-8 km/d depending on ⌀
lay water depth: 3000 m

THE CHALLENGE

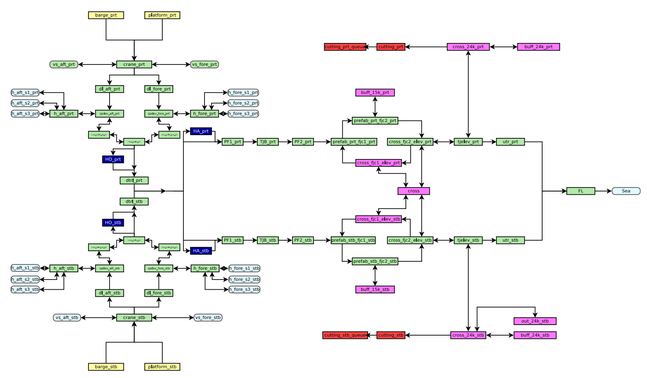
The Vessel's Goals

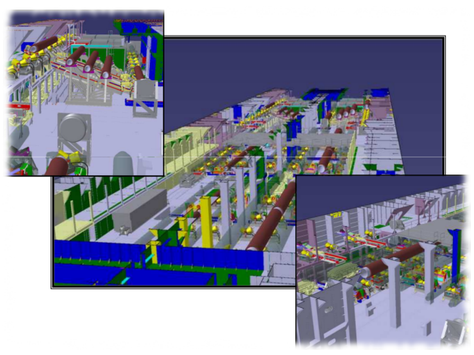
- The Vessel must produce and laid a *precise sequence of pipes*.
  - *Firing Sequence* (FS): The precise sequence of pipes
  - Each pipe in FS has a type (e.g. **A**, **B**, **N**) and a section (⌀)
- The FS must be achieved while respecting some constraints, policies and other secondary goals.
  - Some plants machinery can be disabled
  - Load balancing of prefabrications
  - Vessel's weight balancing must be kept
  - Distribution of pipe's types
  - Safety thresholds for provisioning
  - Vessel autonomy
  - Optimize pipes provisioning
  - ...



Vessel's Plant, Work Process and Pipe Provisioning

- Single Pipes (SJs) are taken from holds and carried to the two *prefabrications*
- In prefabrication triplets of SJs are welded into Triple Joints (TJs)
- TJs are then sent to the Firing Line for being welded to the final FS and laid into the sea
- Stacks are refilled by Barges (pipe carrier vessels)





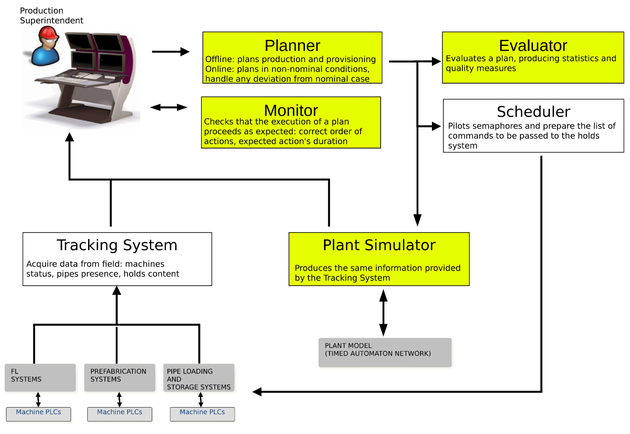
Faults Happen!

- Faults can happen both at plant level and pipe level
- Noticeably, pipes are in a row and their order can be changed only exploiting a limited number of buffers
- When a fault happens, faulty pipes shall be sent to the cutting stations, faulty paths shall be avoided, and the FS must be achieved taking care of remaining pipes in the plant, and re-arranging provisioning

THE PLANNING & MONITORING SYSTEM

The Planning System is built on top of low-level hold handling and hardware level.

- Used both as Engineering Tool and for Live Operations
- Physical Plant can be substituted by a Simulator
- Features a Human-Machine Interface in the Control Room
- Produced plans can be sent to the Simulator, or to the physical plant through the Scheduler



The Planner

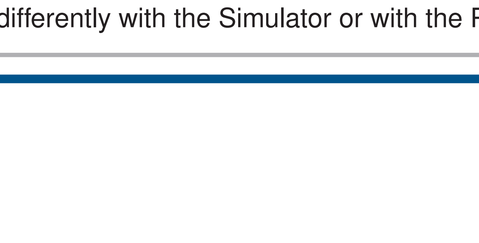
- Generates a *production plan*

- When faults happen, *re-plans* to achieve the goals with the new plant condition
  - When re-planning with *patching*: try keeping minimal deviation from the previous plan

The planner is made of two search engines:

- A graph-based A* heuristics planner for production planning and re-planning
- The provisioning planner
  - *Genetic search*: for large, loosely constrained problems
  - *BFS search*: for small, highly constrained problems

The Monitor

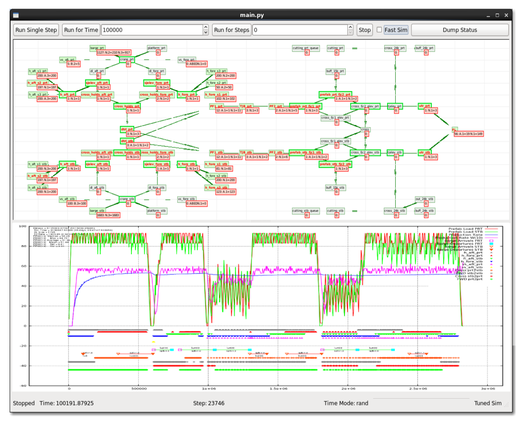


- A graph containing duration and dependency order of actions
- Monitor is notified as the actions are executed:
  - Checks action's durations against the graph
  - Checks action's orderings against the graph

The Plan Evaluator

Produces statistics and quality measures out of the execution of a plan
Examples of important measures are:

- Production Rate (pipes/day)
- Load Balancing
- Working timings
- Barges number and balancing
- ...



The Simulator

- Simulates a Network of Timed Automatons abstracting the Physical Plant
- It is used when Planning System is used as Engineering Tool, i.e. for plan debugging and what-if analysis
- Noticeably, the Planning System interfaces indifferently with the Simulator or with the Physical Plant