AUTONOMY FOR MAERSK

MSC 98

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Highlights from our history

1928: Maersk Line founded with route between Asia and the United States

1972: Maersk Oil produces first oil in North Sea

1975: First container vessel added to the fleet

2013: Triple-E vessels, the world's largest and most efficient container vessels launched

2016: APMM A/S becomes an integrated transport & logistics company and organises into two divisions

1904: Company founded in Denmark with one freighter

1962: DUC established, paving the way for oil & gas business

1972: Maersk Drilling founded

2001: APM Terminals founded

2014: APM Shipping Services established
APMM A/S has become organised into two divisions

**TRANSPORT & LOGISTICS**

- Managed and operated in an integrated manner
- Based on a one company approach with multiple independent and strong brands

**ENERGY**

- Managed and operated as individual business units
- Intent to separate out of APMM A/S
- Develop opportunities for BUs for how to structure outside APMM A/S over the next two years
- Opportunities to grow in the energy space
Transport & Logistics division

**MAERSK LINE**
- Revenue: USD 20,715m
- Underlying profit: USD -384m
- Employees: 31,858

**APM TERMINALS**
- Revenue: USD 4,176m
- Underlying profit: USD 433m
- Employees: 22,615

**SVITZER**
- Revenue: USD 642m
- Underlying profit: USD 89m
- Employees: 2,870

**DAMCO**
- Revenue: USD 2,507m
- Underlying profit: USD 31m
- Employees: 11,292

**MAERSK CONTAINER INDUSTRY**
- Revenue: USD 564
- Underlying profit: USD -53m
- Employees: 5,381

Numbers are from full year of 2016
*The underlying profit is equal to the result of continuing businesses excluding the net impact from divestments and impairments.*
Autonomy in Transportation

Autonomy is already underway in the transportation industry

**Automotive**
- Tesla claims they will have self-driving cars in 2 years, competitors close behind
- $42 billion USD market potential by 2025 according to BCG

**Aerospace**
- Airplanes can already be flown remotely piloted and the technology to fly autonomously exists

**Rail**
- Fully automated trains have existed for many years (e.g. Copenhagen Metro)

**Maritime**
- Remotely piloted vessels exist mainly in defence and marine survey
- Only one autonomous vessel built to date (Defence)
Autonomy in Maritime

The past 12 months have seen multiple MASS projects launched

The Sea Hunter is an USV launched in 2016 as part of the DARPA Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV) program. At 40m with a range of 19,000km, it can stay at sea unmanned for up to 90 days.

The Yara Birkeland will be the world’s first fully electric and autonomous container ship. At 70m with a 100-150 TEU capacity, it will reach remotely piloted by 2019 and fully autonomous by 2020.

Announced in June 2017 at the Autonomous Ship Symposium, Rolls-Royce confirmed it is currently developing a commercial autonomous vessel with an undisclosed partner. This vessel reached remotely piloted in early 2017 with plans to be autonomous by 2018.
Fully autonomous vessel

*It takes more than just control technologies for a fully autonomous vessel*

- Land based control center
- Control and optimization algorithms
- IT infrastructure
- Reliable prime mover / auxiliaries
- Condition based monitoring/ Predictive Maintenance
- Real-time stable and secure high bandwidth connectivity
- Autonomous Control Systems
- Connected Vessel
- Situational Awareness

Electrical Propulsion systems are today the best platform for building vessel autonomy
Maersk Line’s view on autonomy

Our journey to autonomy in 3 distinct phases over time

- AL0 Manual Steering
- AL1 Decision-support on board
- AL2 On-board or shore-based decision support
- AL3 Execution with human being who monitors and approves
- AL4 Execution with human being who monitors and can intervene
- AL5 Monitored autonomy
- AL6 Full autonomy

Phases:
- CURRENT
- CURRENT + NEWBUILD
- NEWBUILD

 CONNECTED  DIGITALIZED  AUTONOMOUS
“Autonomy” is not a goal in itself
Key is to improve the safety, reliability, and efficiency of operations

The aim of “autonomy” is to improve operations

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<td>Collision avoidance</td>
<td>Enhanced situational awareness</td>
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<td>Severe weather avoidance</td>
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<td>Reliability</td>
<td>Technical trouble shooting between vessel and office-based staff</td>
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- Shore-ship **connectivity** is the most immediate enabler of operational improvement
- **Unmanning** is **not** an aim for Maersk Line
- **Regulation** needs to keep up with the pace of technology
Key role for the IMO

• Early response to secure global approach to autonomous vessels

• Legal clarity and secure framework is of utmost importance

• Human element should be part of the exercise as autonomy will require new skills and qualifications in the future

• Maersk supports swift scoping exercise with relevant external input
Thank You
Levels of Autonomy for Ships

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Autonomy – to enhance safety

Scope of this presentation

• Walk through levels of autonomy (LR formulation)
• Illustrate autonomy levels by cases
• Show how incremental steps can enhance safety
• Summary – what do we wish from autonomy
Levels of autonomy (Lloyds Register)

- **AL 0**: Manual – no autonomous function.
- **AL 1**: On-ship decision support
- **AL 2**: On and off-ship decision support
- **AL 3**: ‘Active’ human in the loop
- **AL 4**: Human on the loop – operator/supervisory
- **AL 5**: Fully autonomous – rarely supervised
- **AL 6**: Fully autonomous - unsupervised

Source: LloydsRegister: Cyber-enabled ships, July 2016

AL 0) Manual – no autonomous function.
All action and decision making is performed manually – i.e. a human controls all actions at the ship level. Systems on board may have a level of autonomy, with ‘human in/on the loop’; for example, pms and engine control. Straight readouts, for example, gauge readings, wind direction and sea current, are not considered to be decision support.

AL 1) On-ship decision support
All actions at the ship level are taken by a human operator, but a decision support tool can present options or otherwise influence the actions chosen, for example DP Capability plots and route planning.

AL 2) On and off-ship decision support
All actions at the ship level taken by human operator on board the vessel, but decision support tool can present options or otherwise influence the actions chosen. Data may be provided by systems on or off the ship, for example DP capability plots, OEM configuration recommendations, weather routing.
AL 3) ‘Active’ human in the loop
Decisions and actions at the ship level are performed autonomously with human supervision. High-impact decisions are implemented in a way to give human operators the opportunity to intercede and over-ride them. Data may be provided by systems on or off the ship.

AL 4) Human on the loop – operator/supervisory
Decisions and actions are performed autonomously with human supervision. High impact decisions are implemented in a way to give human operators the opportunity to intercede and over-ride them.

AL 5) Fully autonomous
Unsupervised or rarely supervised operation where decisions are made and actioned by the system, i.e. impact is at the total ship level.

AL 6) Fully autonomous
Unsupervised operation where decisions are made and actioned by the system, i.e. impact is at the total ship level.
Level 0 – typical configuration

**Heading control**
- Set course
- Heading angle
- Auto-pilot
  - Heading
- Steering gear
  - Rudder angle

**Propulsion control**
- Set rpm (telegraph)
- Diesel control system
- Governor a.o.
  - Shaft speed
- Prime mover
  - Power, rpm
Level 1/2 – on ship decision support

- Electronic chart
- Plan track
- Set waypoints
- Autopilot with track control
- Position (GNNS)
- Autopilot with track control

AL 1/2: acknowledge wheel over
AL 3: automatic wheel over
Case for autonomy: A few of observed groundings & bridge collisions in DK

Reason: navigators unaware that course alteration is required

Remedial: integrate autopilot with e-chart & GNNS
Intervene in critical situations

IMO June 2017 M. Blanke
Risk reduction by autonomy: AL 3

Gounding at Bornholm & collision with bridge: navigator on watch unaware of required course alteration

Remedial: Bypass unfit person in the loop

Technology: integrate autopilot / engine control with supervisor automation that has situation awareness

Allow automatic course alteration or let engine control stop vessel

Assure that action minimises risk

Situation awareness from:
- ARPA Radar + GNSS + e-chart
- Electro-optical sensors

COLREG
Autonomy AL 4: Human on the loop

Automated maneuvers will require autonomous navigation to meet COLREG

Electronic outlook is a key element to high-autonomy navigation

Sensor fusion to track objects, interpret information, create situation awareness

Implement COLREG rules, add vessel track prediction, use e-chart

Human operator can intercede and over-ride
Levels 4 & up – human on the loop to fully autonomous

- Electronic chart
- Cruise Planner
- On-board supervisor
- Ground segment supervisor / control possible
- Sensors: Radar, GNNS, lidar, electro-optical, AIS + others
- Information Fusion
- Situation awareness
- COLREG re-planner
- Path prediction
- Autopilot track control
- Prime mover control
- Remote command / control possible
What we want from Autonomy

What autonomy is doing
- Remote supervision + control

What autonomy can do
- Digest & simplify information
- Situation awareness
- Warn if danger
- Suggest safe manoeuvres

What autonomy could do
- Intervene if situation is critical
- Navigate autonomously
- Call shore segment if needed
- Quay to quay service

Want autonomy might do

Enhanced outlook
Decision support
Safety & new services