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Abstract. The complex picture of maritime transport involving more than 100 thousand ships, more than 8000 ports and a large number of stakeholders fulfilling different roles and being responsible for different processes means that providing up-to-date and timely information during port calls is a complex task. In addition, there are requirements to reduce both the environmental footprint and costs of the maritime transport. From 2019, the International Maritime Organization (IMO) made it mandatory to accept electronic clearance of ships entering foreign ports, meaning that the digitalization of ship-port interfaces to support the port call processes has become an important topic. Further, this means that the interoperability between a large number of ICT systems to support the end-users related to a port call, must be ensured. This paper describes the model in the middle, by which we mean a "least common multiple" regarding data elements and data models to support a consistent exchange of information between preferably all involved stakeholders during a port call.

1. Objective

The last year's disruption of the sea transportation has shown the importance of the role that the ports have in the wider supply chain. The complex picture of maritime transport involving more than 100 thousand ships [1], more than 8000 ports [4] and a large number of stakeholders fulfilling different roles and being responsible for different processes means that providing up-to-date and timely information during port calls is a complex task. In this regard, the digitalization of the interface between ship and shore and the related processes will become increasingly important. It is important to improve the quality and availability of data to be exchanged before, during and after a port call and to harmonize the standards to allow reliable and efficient information exchange between ship and shore systems. There is an overlap of information needs, both in the mandatory reporting to authorities and in the information needed to ensure efficient Just-in-Time arrival, timely execution of port services, safe navigation to the port, and automation of cargo operations and the mooring process.

This paper gives an overview of the relevant actors, processes and information elements related to ship-shore interaction during port calls with focus on the commonalities between operational services, authority processes and nautical operations. Focus will be on the "model in the middle" by which we mean the commonalities regarding information requirements as seen by the different actors and processes related to describing the timing and locations for a port call to be as efficient as possible.

Chapter 2 gives an overview of the methodology, while Chapter 3 describes the background and structure of the IMO Reference Model that is the main topic of this paper. The technical implementation of the reference model can be done by ISO 28005 on Electronic Port Clearance (Chapter 4), while other initiatives and related work are described in Chapter 5. Three sub-models in the reference model, namely for Location, Timestamp, and Maritime Service are described in Chapter 6, 7, 8 and 9. The top-level processes are described in Chapter 10 and the related actors are listed in Chapter 11.

2. Overview of Methodology

The paper defines relevant actors related to the ship operation, port and terminal services. Further, a description of the high-level processes is given. Various initiatives regarding standardization of the information is described. This will focus on information to describe the timing of the port arrival, departure and service execution and also information to describe locations related to the port call.

The goal is to outline the requirements to a harmonized description of timing and locations to ensure efficient port calls, both related to safe berth-to-berth navigation, berth planning done by the terminals, efficient execution of port services and cargo operations, improved information exchange with hinterland transport, timely execution of port and terminal services, and Just-in-Time arrival of ships which are closely linked to voyage optimization. Even if the information is available at different points in time and with different granularity for each use case, it is important to describe the commonalities that still exist, to ensure efficient interoperability among ship-side and shore-side ICT systems, and thus ease the operation both for the ships and the ports.

3. The IMO Reference Model

An important contribution to the "model in the middle" comes from the work done by the International Maritime Organization (IMO) in cooperation with the World Customs Organization (WCO), the United Nations Economic Commission for Europe (UNECE) and the International Organization for Standardization (ISO) through their establishment of a common reference model [2]. The original purpose of the IMO Reference Model was to ensure interoperability between government-to-government data exchanges (WCO), international trade data exchanges (UNECE) and ship operational data exchanges (ISO) in the scope defined by the Convention on Facilitation of International Maritime Traffic (FAL Convention). This is also often referred to as the scope of the "Maritime Single Window" (MSW).

More generally, the "model in the middle" contains a set of data elements that are given a harmonized description and a minimum representation requirement (data formats, code lists and business rules). This is done to ensure that each data element has a unique interpretation and thus can be used in various contexts with a well-defined meaning. This is important to support the "report once"-principle and at the same time ensure a consistent and clear information exchange between actors during a port call. One example of a data element that needs a clear definition, is the arrival and departure time to/from the port. Here, both the type of the timestamp must be defined (whether it is an estimated, actual, planned or requested time) and a specific location in the port (in some cases it is enough to specify the port with no further details). In addition comes the definitions of arrival and departure, for instance related to whether it is defined by the first/last line onshore/onboard, when the ship is ready for boarding etc. Also, the actor responsible for each of the timestamps and the related processes where this data is exchanged, must be defined. More generally, the data elements defined in the reference model will be relevant for one or more domains, which is shown as FAL Forms, JIT (Just-in-Time) Arrival, Certificates, Ship Reporting etc. in Figure 1. From the top, the picture in Figure 1 shows the following as described in the following sections:

3.1. *Controlling documents*

These are the legal basis for the reporting requirements and the data exchange between actors engaged in the port call.

3.2. *IMO Data Set*

This is the list of common data elements defined across all domains relevant for a port call and the voyage.

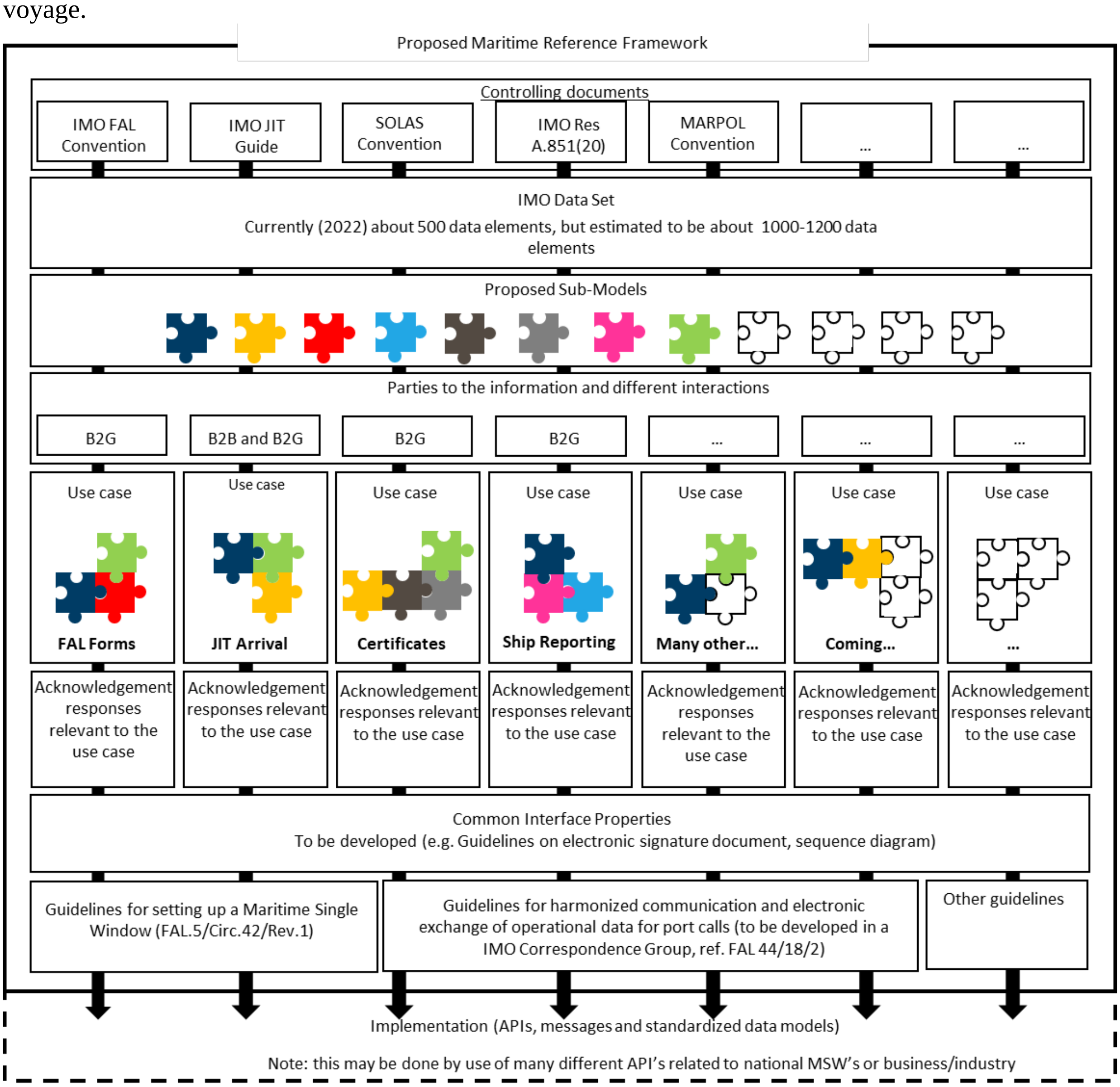

Figure 1. Sketch of a Maritime Reference Framework as proposed to IMO in EGDH 6/9

3.3. *Proposed Sub-Models*

The Reference Framework can be structured in sub-models covering specific topics, for instance static information about the ship, cargo, dangerous cargo, health, maritime services, waste, crew, passengers, timestamps, and the port call itself, among others.

3.4. Parties to the information and different interactions

This is the various types of actors which is relevant for the exchange of information described in the proposed maritime reference framework. Roles and actors are further described in Section 11.

3.5. Use cases

These are the different domains that the data elements and sub-models may be used for. Examples here are for reporting on the FAL forms, Just-in-Time arrivals, certificate reporting, mandatory ship reporting, etc. For each use case, a description of the relevant acknowledgement responses must be included.

3.6. Common Interface Properties

Across each of the domains and systems, common guidelines on electronic signatures, meta data on the message exchange, sequencing, and similar properties to ensure safe and secure data exchange, must be described.

3.7. Guidelines

This includes guidelines for setting up each of the types of systems relevant for the maritime framework, for instance guidelines for setting up Maritime Single Windows (MSWs), guidelines for the exchange of operational data needed for a port call, guidelines for how to use the proposed maritime reference framework to interface terminal operation systems, among others.

3.8. Implementation

The implementation-specific tasks are shown at the bottom of the figure. This includes the development of technical standards, message formats and APIs. Already existing examples here are the mappings that are described from the IMO reference model to the UNECE, WCO and ISO 28005 data models.

3.9. Example

An example on how the bricks in Figure 1 can be understood is the following: The dark blue brick at the "Proposed Sub-Models"-level can represent for instance the sub-model for the timestamp data set (see Section 7). Then, at the use case level, Figure 1 shows that this sub-model is used in the FAL forms use case, in the Just-in-Time Arrival use case and in the Ship Reporting use case. Similarly, the red brick can indicate that for instance the crew sub-model is used only in the FAL form use case.

The IMO Reference Data Model and the IMO Data Set support the semantic harmonization between the various reporting requirements (Controlling documents, top in Figure 1) and also the coordination between different technical implementations as shown at the bottom of Figure 1. Currently, the IMO Reference Data Model and Data Set are mapped to three different data models:

- The customs domain (the World Customs Organization (WCO) data model)
- The trade domain (the United Nations Economic Commission for Europe (UNECE/UNCEFACT) Core Component library)
- Ship-port-specific domain: The standard for electronic port clearance (ISO 28005-2 data model [3]).

The main concepts from the IMO Reference Model that are important for port call optimization are the operational data covering Location, Timestamps and Maritime Services. These concepts are now being implemented in a technical standard through the work done together with several maritime stakeholders through ISO TC8, both industry partners, authorities, and standardization organizations, to extend the 28005-2 standard. 28005-2 is further described in the next section.

4. ISO 28005 Electronic Port Clearance

The ISO 28005-series of standards maintained by ISO TC8 contains data elements covering the requirements for ship-shore reporting for authority information as defined in the following:

- Most required information sets as defined in the FAL Convention to be sent at arrival or departure:
  - General Declaration (FAL Form 1)
  - Cargo Declaration (FAL Form 2)
  - Ship's Stores Declaration (FAL Form 3)
  - Crew's Effects Declaration (FAL Form 4)
  - Crew List (FAL Form 5)
  - Passenger List (FAL Form 6)
  - Dangerous Goods Manifest (FAL Form 7)
- The document required under the Universal Postal Convention for mail (a reference to the physical or electronic document)
- Maritime Declaration of Health as based on the Maritime Declaration of Health (MDH) from WHO, 58th World Health Assembly, WHA58.3.
- Security-related information as required under SOLAS regulation XI-2/9.2.2 (ISPS code).
- Advanced electronic cargo information for customs risk assessment purposes
- Advanced Notification Form for Waste Delivery to Port Reception Facilities, based on the recommended reporting on ship-generated waste as defined in MEPC 644, which is mandatory within the European Union, as described in EU/2000/59.
- Required reporting as defined in the bulk loading and unloading code IMO Resolution A.862.
- Mandatory ship reporting system (MRS) requirements as defined in IMO Resolution A.851.
- ETA reporting to pilot station as defined in IMO Resolution A.960.

The new version (2021) of the ISO 28005 standard was updated to cover the data element list and the data model described in the IMO Reference Data Model, as described in the updated IMO FAL Compendium in FAL.5/Circ.43 from 23 October 2020 (IMO Compendium, 2021).
The information in 28005 is described as XML types in an XSD and also as classes in UML diagrams. The ISO 28005 standard also describes messages and the protocol on how to exchange these messages, including clearance, update, cancellation, receipt and acknowledgement. Most important, 28005 contains a mapping to the IMO Reference Model that ensures that systems implementing this standard is compatible with the semantic model agreed on by all partners involved in the development of the IMO Reference data model and data set.

Further, work has started in ISO TC8 to extend the 28005-standard with operational data related to the port call, especially the timestamps, identification of locations, and the definition of services. The aim of this work is to give a technical description of the data exchange between ship and shore for custom declarations, arrival times and completion times of cargo services, among others, including the synchronisation between each actor, and based on the semantic reference model agreed on by IMO and all representatives participating in the EGDH (Expert Group on Data Harmonization) working group.

5. Other Initiatives and Related Work

5.1. International Task Force Port Call Optimization

ITPCO [5] is an industry initiative to optimize the port call process in a trade agnostic manner from the contracting phase where a ship is chartered either for bulk or container and all the way through the port call and departure from the port. This process focuses on covering both bulk and container cargo and also to ensure that the processes handle the fact that decisions regarding the ship operation is made by the captain, including the timing and ordering of services in the port and terminal. The ITPCO process map gives the AS-IS-situation, except for the usage of the various time stamps, since today, only the usage of estimated times is common.

5.2. PortCDM/S-211

PortCDM focuses on the actual port call optimization and does not cover the processes before the port call as the contracting phase and how this influence the port approach from the pilot boarding place to the berth. The PortCDM/S-211 process model is an attempt to have an integrated view of all plans related to a port call, that means, plans for the port arrival and departure, berth management and for the various services to be provided to the ship, and to considered this as a whole. PortCDM/S-211 describes each of the port call process steps and the related sub-processes. For each step, a list of events is described. The PortCDM initiative is standardized by IEC in S-211, and this describes the port call message with the necessary information elements to cover the timestamp, location states and events to support optimization of the port call and Just-in-Time arrival of the ship to the port. This model covers data elements needed to be exchanged between the ship and port authority to cover the planning, execution and completion of the port arrival, port stay and port departure and also the synchronization of port and terminal services both in the planning phase, execution phase and completion phase.

5.3. DCSA

DCSA is an organization consisting of nine container shipping lines that has defined a Just-in-Time concept for port call optimization based on the work done by ITPCO. DCSA defines five high level port call processes as follows:

- *Berth Arrival Planning:* The carrier and terminal operator align on the short-term plan and the approximate time of availability of the berth.
- *Pilot Boarding Place Arrival Planning:* The carrier (represented either by the captain of the ship, the operation centre or the agent) and the port align on the arrival plan. A planned time at the Pilot Boarding Place (PBP) is agreed.
- *PBP and Berth Arrival/Start Cargo Operations:* The ship arrives at the PBP and is manoeuvred to the berth where cargo operations will start.
- *Cargo Completion & Port Departure Planning:* The terminal operator shares the planned time of cargo operation completion with the carrier, which enables departure planning with the port.
- *Cargo Completion & Berth Departure:* Cargo operations are completed, port clearance is granted, and the ship departs for the next port from the berth.

6. Operational Information for Port Calls

Since several different processes, actors and domains are involved in a ship visiting a port, the standardization of information to be exchanged should be held at a minimum. Several stakeholders (IMO, ISO, ITPCO, DCSA, S-131, IHO) have defined the following three: Location, Timestamp and Maritime Services as shown in Figure 2. This figure shows basic operational information needed before, during and after a port call.
The following sections will describe this information to ensure consistent exchange of data ensuring timing of the port arrival, departure and service execution and also information to describe locations related to the port call.

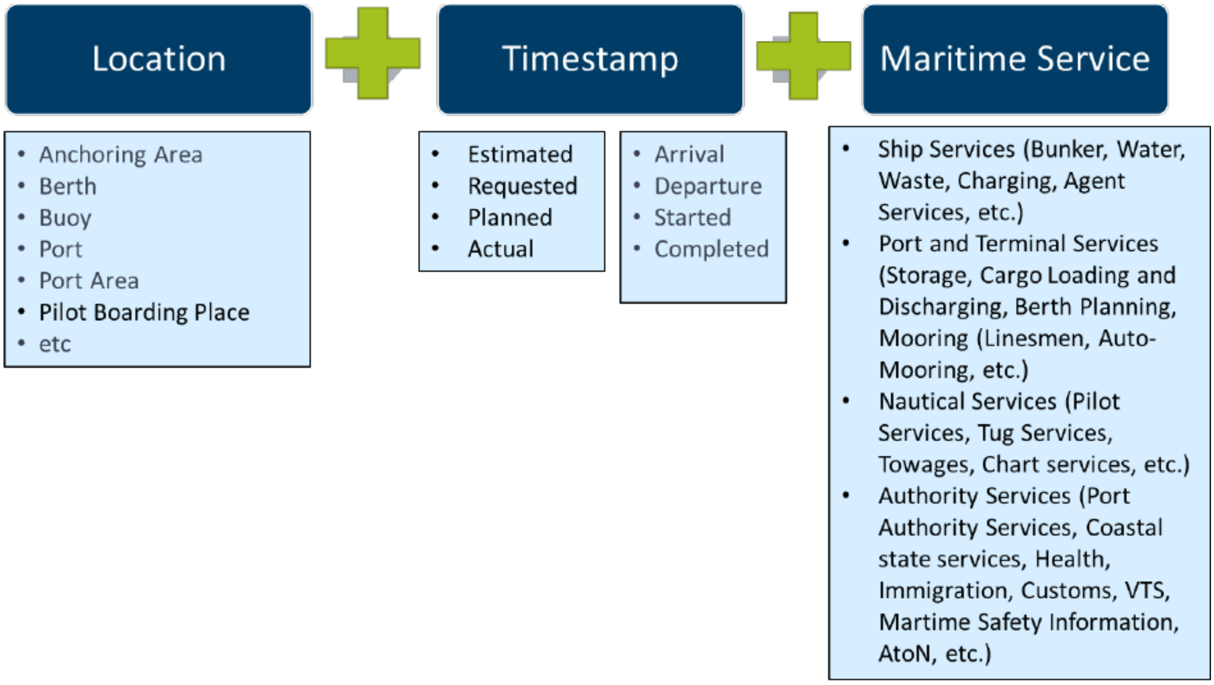

Figure 2. Operational Information for Port Calls

7. Timestamps

The IMO Reference Model gives a semantic definition of timestamps for port arrival, port departure and for service start and end as shown in Figure 3. ITPCO has described the processes using these timestamps, and the corresponding sequence diagram details are shown in Figure 4.

8. Locations

To ensure easy interoperability between the various systems and actors involved in a port call, it is important to be able to identify locations in the port for different usages. Several initiatives are relevant here, both from the sea side and the shore side. IHO is maintaining the S-57/S-100 standard covering ECDIS onboard the ships, while national representatives handle the mapping in the ports. In addition to this comes the different ways to identify locations for the different modes; road, rail and sea, and also for the port and terminal infrastructure. The IMO Reference data model has currently (2022) included a simple definition of locations. The port is identified by a UNLOCODE (or with the name if a UNLOCODE does not exist), and a location in port is defined as "the name of the berth, terminal or station where the ship is located in the referenced port". In addition, to handle the Just-inTime concepts, the concepts as listed in Figure 5 are defined, similar to what is done by IHO, ITPCO and others. The IMO Reference data model does not describe the data format of these fields other than being free text (or LAT/LON for positions). For the technical data model as for instance ISO 28005, this must be defined as GLN-codes from GS1, MRN-numbers from IALA or by other means.

9. Maritime Services

Figure 6 shows the definition of maritime services from the IMO Reference model. In ITPCO, the services are divided into:

- *Nautical services:* Services related to the safe passage and berthing of the vessel.

- *Vessel services:* Services related to the vessel, for instance bunkers, lube oil, potable water, provisions, stores, waste per IMO/MARPOL class, repairs, vetting, flag survey, periodic maintenance and others.
- *Cargo services:* Services related to the cargo, for instance cargo handling, cargo survey, lashing and others. The definition of maritime services is important to be able to link the reference model to the IHO S-100 framework for e-navigation [6] and its Common Maritime Data Structure [7][8]. Also, a clear definition of maritime services is needed to be used in the exchange of operational information before, during and after a port call to ensure efficient booking of services, follow up of service execution during the port call, and the completion of the services.

Time stamp	Definition
Date and time of arrival – actual	The date and time the ship arrives at a specified location, ATA.
Date and time of arrival - estimated	The date and time the ship is estimated to arrive at a specified location, ETA.
Date and time of departure - actual	The date and time the ship departs from a specified location, ATD.
Date and time of departure - estimated	The date and time the ship is estimated to depart from a specified location, ETD.
Date and time of arrival - planned	Date and time the ship plans to arrive at a specific location, PTA
Date and time of arrival - requested	The date and time the ship is requested to arrive at a specified location, RTA
Date and time of departure - planned	Date and time the ship plans to depart from a specific location, PTD
Date and time of departure - requested	The date and time the ship is requested to depart from a specified location, RTD
Date and time of service start - estimated	The date and time a service provider estimates a specified maritime service will start, ETS.
Date and time of service start - requested	The date and time a ship requests a service provider to start a specified maritime service, RTS.
Date and time of service start - planned	The date and time a service provider plans to start a specified service, PTS.
Date and time of service start - actual	The date and time a maritime service provider starts a specified service, ATS.
Date and time of service completion - estimated	The date and time a service provider estimates a specified maritime service will be completed, ETC.
Date and time of service completion - requested	The date and time a ship requests a service provider to complete a specified maritime service, RTC.
Date and time of service completion - planned	The date and time a service provider plans to complete a specified maritime service, PTC.
Date and time of service completion - actual	The date and time a service provider completes a specified maritime service, ATC.

Figure 3. IMO Reference Data Model timestamps

10. Ship-Shore Processes

As part of the work to describe autonomous ships calling at small ports and especially the mother/daughter vessel concept in AEGIS, an overview of processes related to ship operation, port and terminal operation and cargo operation were described, Figure 7. The processes cover both the phases Marketing, sales and alignment, Planning, Execution, and Completion, with the main focus on Planning and Execution.

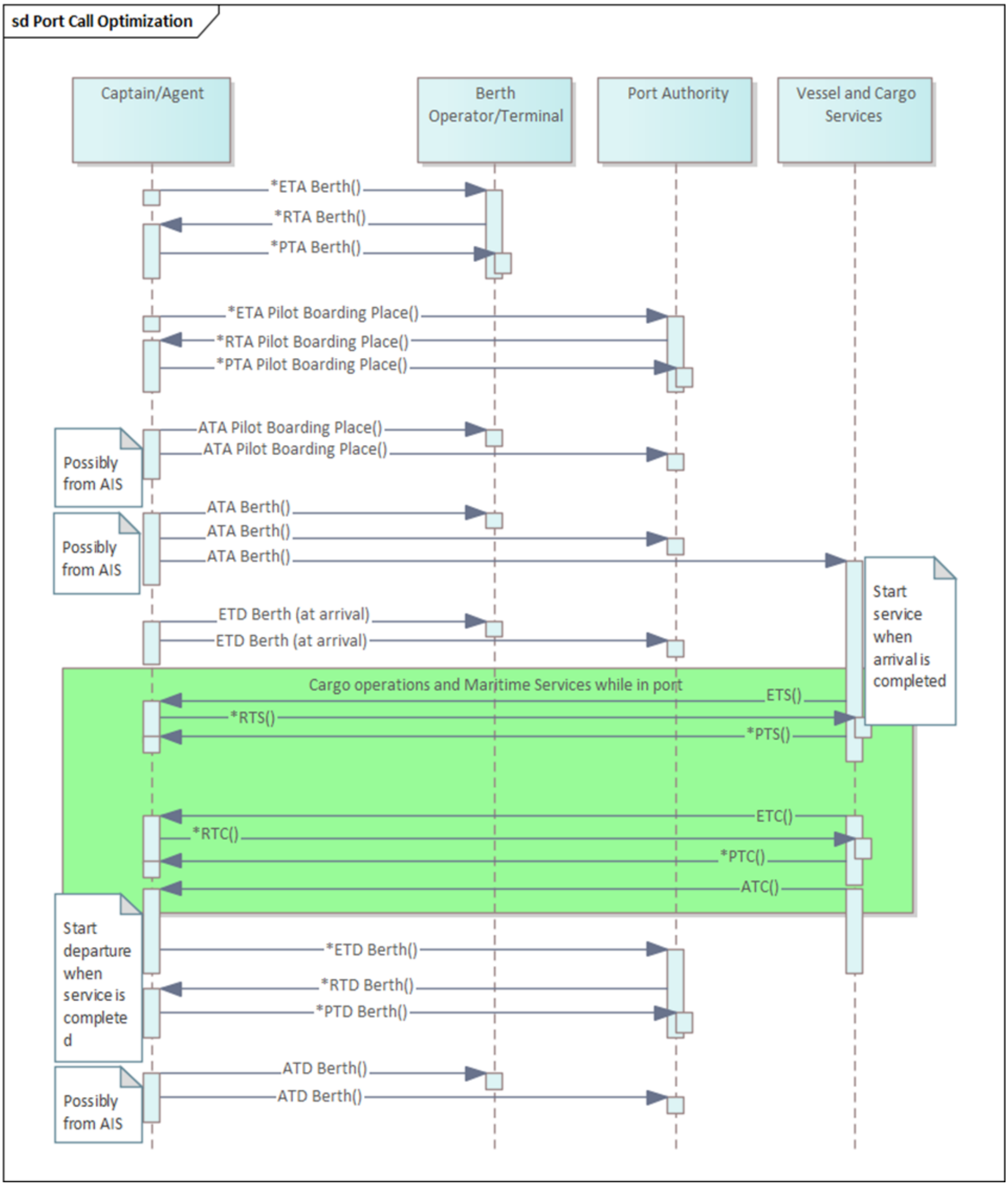

Figure 4. Sequence Diagram for timestamps

10.1. Voyage Planning

Based on ship details and the booking and cargo information, the ship representative (ship operation or captain) sets up the stowage plan (bay plan) (done by ship operation or captain) and the loading and discharge plan for each port call (done by ship agent or ship operation). This includes planning of the equipment that has to be used during the loading and discharge operation and the timing of the operation.

Included here is also the plan for the port call when several terminals are to be visited and several port and terminal services are needed in addition to berth and mooring, for instance for onshore power supply, bunkers, waste collection or fresh-water supply.

The shipping company may also need a collection plan and discharge plan describing interaction with hinterland transport, that is, how and when cargo will be delivered to the ship and fetched from the quay after discharging.

If the Requested Time of Arrival (RTA) to the pilot boarding place and to the berth could be sent directly to the (ECDIS), for instance using the S-421 route exchange format, this would provide the ship with better information to adjust their speed to arrive at the port in a timely manner.

Anchorage	An area in which ships anchor or may anchor (IHO Hydrographic Dictionary S-32)
Terminal	A number of berths grouped together and provided with facilities for handling cargo (IHO Hydrographic Dictionary S-32)
Pilot Boarding Place	At sea, the meeting place to which the pilot comes out.
Berth	The space assigned to, or taken up by, a ship when anchored or when lying alongside a quay, wharf, jetty, or other structure.
Berth Position	The position along the line of a berth, specified by one point (e.g. bollard, manifold or ramp number), allowing the ship to berth in the correct position along the berth.

Figure 5. IMO Reference Data Model for JIT Locations

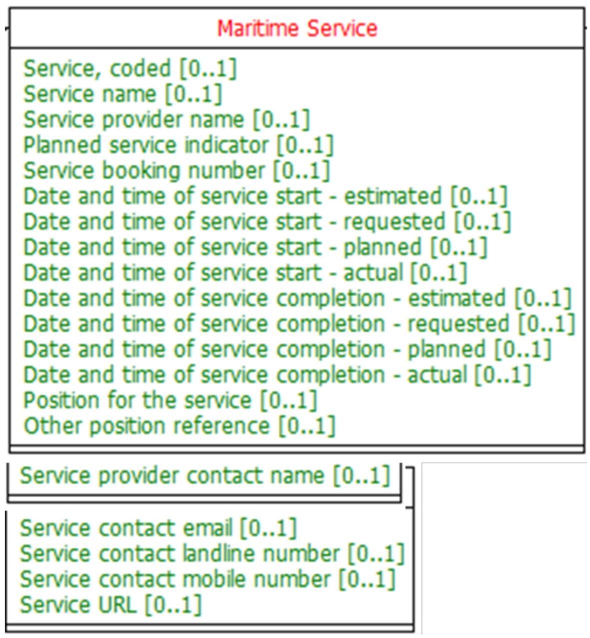

Figure 6. IMO Reference Model Maritime Service Data Elements

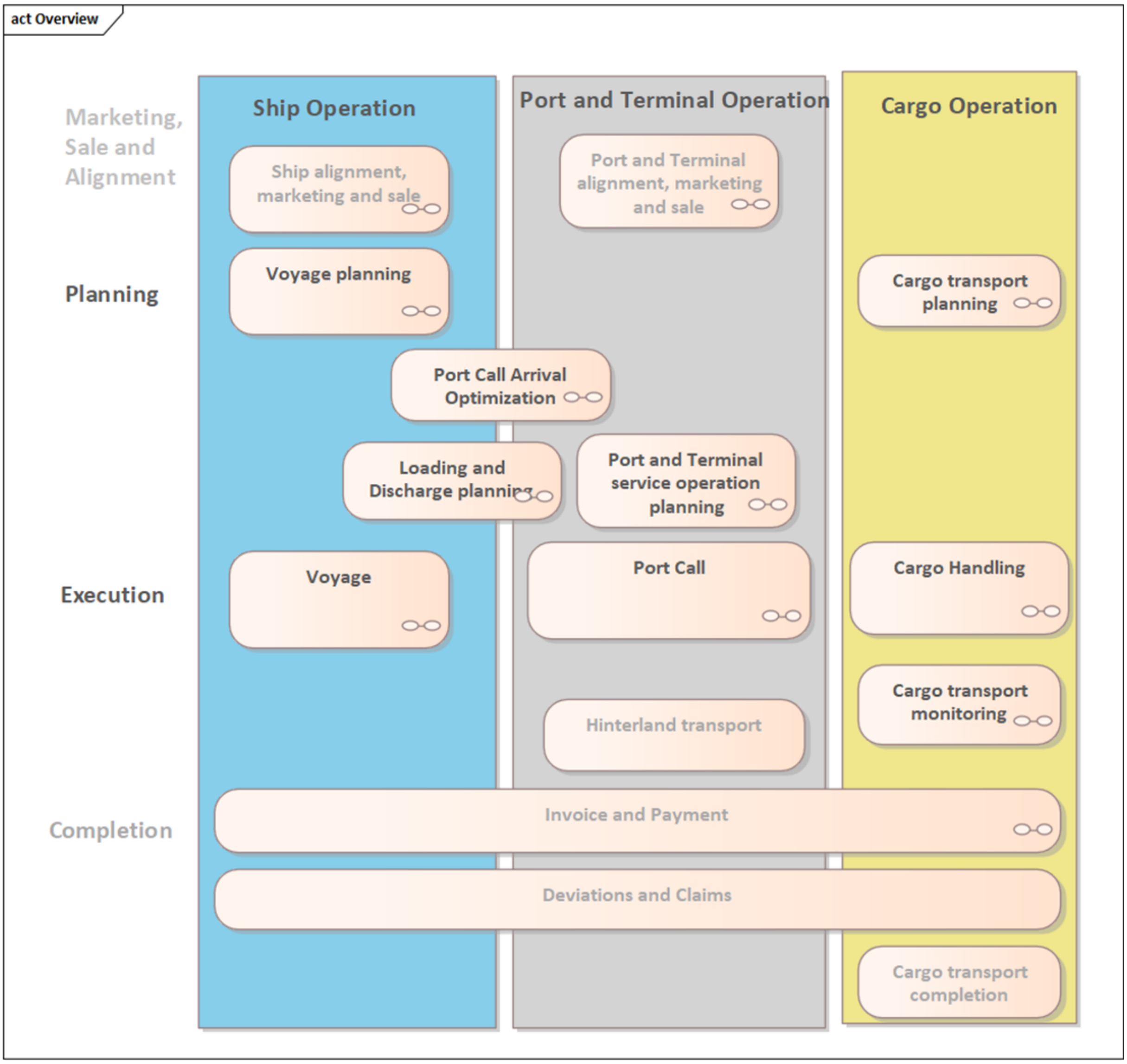

Figure 7. Port Call Processes [from AEGIS]

10.2. Port Call Arrival Optimization

ITPCO has given a very detailed description of the port call arrival optimization [5]. The basic principle is that the ETA has three stages, the ETA proposed by the captain or ship agent, the RTA (requested time of arrival) proposed by the terminal based on the ETA from the captain and the planned arrival time confirmed by the captain (PTA). To improve the terminal service operations, updates of the various time stamps must be given to all involved actors throughout this process. The planning of the arrival time may have several iterations, where the ship agent informs about changes in the ETA and ETD every day, which means that the loop of ETA-> RTA->PTA can be repeated several times.

Berth planning for a ship at the arrival port is usually organized by the terminal operator of the berth. The terminal operator tells which ship will be moored at what time, at which berthing position and which side should be alongside.

By giving the ship a better estimate of the arrival time to the berth, the ship can optimize its speed towards the port. This will have significant impact on the environment, since reduced speed will give large reductions in overall emissions. Also, improved berth planning will improve the hinterland transport planning when the cargo is transferred to another transport mode. The same will be the case for trans-shipment to for instance a mother or daughter ship.

10.3. Loading and Discharge Planning

Loading and discharge planning is done as part of the port call. As the loading and discharge approach, more and more information about the cargo will be available to the shipping company and the terminal operators. The shipping company sets up the handling instructions for cargo, also called shipping instructions, based on cargo information either from the booking they have received and confirmed, or from the transport contract that they have agreed on (typically for bulk cargo). Based on the handling instructions, the shipping company creates the sea waybill including a description of possible dangerous goods. Further, the shipping agent sets up the loading plan and discharge plan based on the sea waybill. These plans are used as input to the stowage plan (bay plan) of the ship. The stowage plan is created by the captain. The terminal plans the loading and discharge operations based on both the loading and discharge plans and the stowage plan (bay plan). Also related to the cargo flow, the shipping company and the terminal exchange information about empty containers, that is, the shipping company can request a specific container or just some containers, and this information is provided by the terminal. Optimalization can be done in the terminal, for instance by using the loading lists prepared by the shipping operator: The terminal can use this to order the containers according to this plan.

10.4. Port and Terminal Service Operation Planning

The port and terminals are the main actors in this process, consisting of the planning of operational activities according to the contract between port and terminal, and the shipping company. Also, interaction with various service providers and infrastructure providers in the port and terminal is part of this process. The result of this planning should be a clear definition of how the port call is performed regarding exchange of information, which ship movements are expected in the port, which ship services are needed and the timing of this. This information may be noted in an execution plan for the port call. In addition, the port and terminal service operation planning consists of each service and infrastructure provider having to plan their work and resource utilization with respect to each of the port calls. This includes planning of the traffic flow in the port and ensuring that safety aspects are maintained. For services that may be autonomous, it includes a clear definition of the requirements to be fulfilled before the operation can start and the responsibilities during the operation.

Resource allocation is a key activity in this process which contains identification and allocation of terminal and port resources needed during a port call. Security aspects and needs related to public inspections have to be taken into consideration in the planning. It must be possible for the regulators to execute inspections of goods e.g., customs clearance and health inspections. In cases of dangerous goods, safety and security are issues which must be planned for in accordance with regulators requirements and needs. Agreeing on the start and end times for the services is an important part of the resource allocation.

Booking is the process confirming that resources are made available for the required service based on the resource allocation process. This is based on the agreed timing of the services, the cargo information and the handling instructions.

Port planning for a ship arriving in a port is usually organized by the port authority, based on the berth planning done by the terminal located in the port. The port authority approves the request for a ship to enter the port and gives information about the pilot boarding place, if relevant. Port authorities often share their port planning with Vessel Traffic Services (VTS), for instance through VHF communication or a MSW, or as in Norway, through SSNN.

Ship services are usually planned by the ship agent together with the captain. The role of the ship agent is to coordinate with the ship service providers in the terminal, for instance for services as bunkers, provisions and waste collection. Cargo services are usually planned by the terminal in collaboration with the captain, and this requires that the terminal has a good overview of the operation of all the different service providers in the terminal to be able to set up a good plan for the ship stay. The terminal needs to know the various cargo services well in addition to be aware of services that requires clearance from the port authorities or the availability of crew on deck.

10.5. Cargo Transport Planning

The cargo transport planning coves the processes where the transport user (cargo handler) prepares customs and other import/export documents which require knowledge about public laws and regulations at national and international level, prepare special handling requirements which require information and knowledge about regulations and laws in different countries e.g. how to handle dangerous goods, environmental requirements related to the transport of cargo, and safety and security requirements that apply.

10.6. Voyage

The voyage consists of the sailing, the ship approaching the port, the port call and the ship departing from the port. Sailing includes the safe navigation of the ship using various e-Navigation tools, weather forecasts etc., and also noon-reporting to the ship operator and MRS and VTS reporting to public authorities. For border crossing, customs reporting may be needed. When it comes to cargo, it may include cargo monitoring to ensure that transport companies can give information to the transport users about status of the cargo. Other cargo reporting may include reporting of cargo information to other public authorities according to international or regional laws and regulations. Updates about the next port call may be received from the port or the ship operator. AIS and possibly other sensor information is made available for shore actors and other ships during the voyage. For the mother-daughter concept, position and status updates between the participants are important.

Ship departing from port includes departure reporting to the port and completion of the statement of facts that summarize all activities performed, including the timing, during the port call.

10.7. Port Call

The port call (ship-port operation) describes the interaction between the port/terminal and the ship during a port call. A port call consists of anchoring (entering and leaving), berthing, performing some port/terminal services including loading and discharging of cargo, then leaving the berth, and possibly movements to other terminals, berths, or anchorages (in-port movement). The information exchange related to port calls include timestamps needed to support Just-in-Time arrival/Port Call Optimisation, authority reporting, cargo loading/unloading, and information about port and terminal services that are needed during the port call. In the execution phase, also information needed to actually execute the operations must be identified, for instance related to autonomous cranes and mooring systems, electricity services and safety and navigational issues.

10.8. Cargo Handling

Cargo handling includes unloading and loading of cargo and interaction between the terminal and the ship. Crane operations are main services in these activities. During this activity, the transport user needs to get tracking information about the cargo. This information is often given to the user by agents based on information from the ship and terminal. For cargo handling involving autonomous functionalities, this process will lead to an extended information exchange between the ship, the terminal system and the crane. Also, the positioning of the ship, the cargo and the cranes will be essential, in addition to the status of the operation. Also, the autonomous crane will need information about the weight and volume of the cargo, the position it is stored, and where it is to be placed.

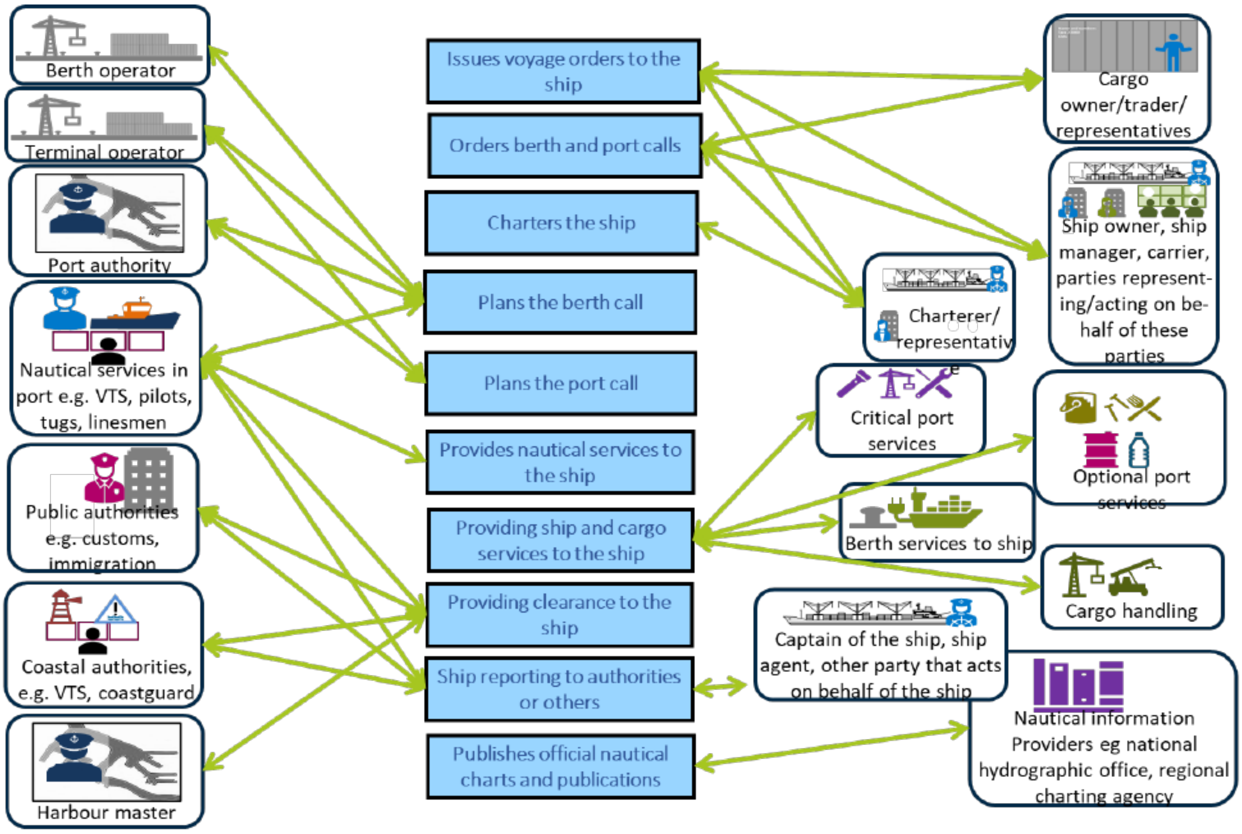

Figure 8. Overview of Actors and Roles

10.9. Cargo Transport Monitoring

During the execution of the cargo transport, the shipping company must ensure monitoring of the cargo handling and the cargo status, monitor the delivery progress, handle deviations during the cargo movement, keep track of commercial operations relevant for the cargo, for instance that the owner has changed, and also to follow up on authorities for customs and cargo clearance (reporting to authorities in accordance with law and regulations about changes and deviations).

When a container is registered for import clearance, the following happens: For customs clearance, each container is assigned a number identifying the container and also the terminal/customs storage and the date. Based on this, a cargo number is generated. This is registered in the customs system by the agent. Then, customs can start their cargo clearance, and after that possibly do inspections. When the terminal gets the generated cargo number from customs, they can release the goods.

11. Actors

Figure 8 gives an overview of the actors related to a port call. The blue boxes in the middle show different roles that the actors must fulfil. Each role can be fulfilled by several actors, and each actor can fulfil several roles.

12. Conclusions

This paper proposes a maritime reference framework containing the different layers that are needed for a "model in the middle" to be able to describe efficient interoperability between systems and stakeholders before, during and after a port call. Especially, the several sub-models are used to describe the commonalities between the different actors and systems to avoid having one large model that could be difficult to define and maintain.

The main benefit of the IMO Reference Model is to ensure a unique definition of concepts related to ship-shore data exchange. This ensures the following:

- Agreement across many stakeholders: IMO as the owner of the IMO Reference Model is supported by several maritime organizations that are involved in the development and maintenance of this model. This ensures its uptake in maritime transport. Also, standardization bodies as ISO, IEC and IHO are involved in the work in addition to organizations representing other domains than the maritime (UNECE and WCO).
- Agreement across many domains: The data elements defined in the IMO Reference Model can be used to ensure interoperability between systems covering different domains, as reporting to port states, terminal and port service systems covering operational data related to a port call, and systems for charts and port assets covering nautical data.
- A common reference model will pave the way for reuse of data in several contexts by different stakeholders, given that the data is clearly defined. This will support the report once – principle of maritime single window systems.
- Clear definitions of a set of data elements that have been agreed on by several stakeholders will ensure efficient interoperability between systems and the possibility to support digitalization of earlier manual processes related to ship reporting and ship operation. However, this will also require a clear description of the system interactions.

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