

Macro-Micro Schedule Architecture Greenfield Fab Project Case Study

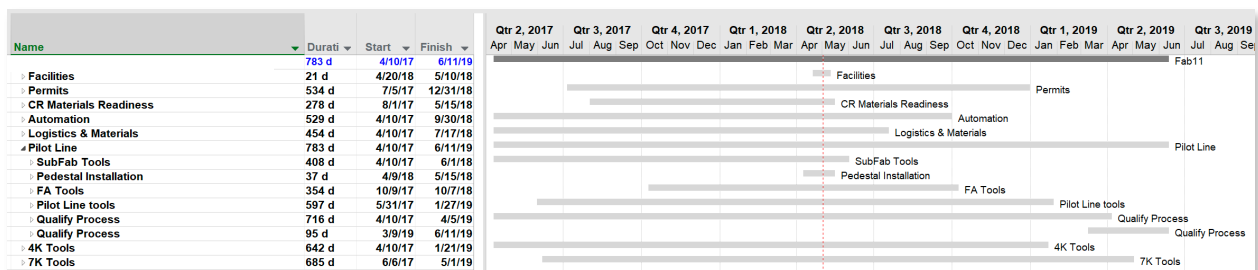
The ramp schedule is broken down into a series of ramp steps, the first ramp step being the Pilot Line (to Risk Start) followed by 4K and 7K Wafer Outs Per Month (WOPM). Over time, more ramp steps will be added to the schedule. There are two basic parts to the schedule:

1. The infrastructure needed to bring up the fab (Facility, IT, Automation, Logistics, etc.) and
2. The tools necessary for each ramp step. These are further broken down by major tool group (Pilot Line (process) Tools, Subfab tools, FA Tools, etc.). For the initial pilot line, there are greater than 170 process tools in the schedule.

Each tool has a target release date (when the tool is fully qualified) that is based on achieving the desired ramp step at a particular time, determined by IE. A tool coming in later than the target would cause the ramp step to occur later (delay it). The target date is determined by IE and is based on an analysis of the process steps and specific tool timing requirements.

The schedule is the instrument that manages all the major work and dependencies across all organizations that, when linked up, gives us a predicted end date. Because the schedule is updated every week (and in some cases daily), it also gives us the visibility into the status of each area so we know exactly where we are and what tasks are driving the end date.

The top-level of the FabX macro-schedule is shown below (this is an example and can change constantly).



In more detail, the key areas are:

- Key Facility/Construction Dates:
 - Whilst the FabX construction schedule is managed separately, the FabX macro-schedule includes key dates that impact the FabX tools, i.e. move-in, install, hookup and qualification.
 - Examples of such dates are EIA report, Permits, Materials, Warehouses, Utilities, Gases, Chemicals and of course, Clean Room ready, i.e. the point in time that tools can be moved in to the Clean Room.

These dates are implemented as “Touchpoints” in the FabX macro-schedule. Touchpoints are milestones with a date and represent the point in time when two independent

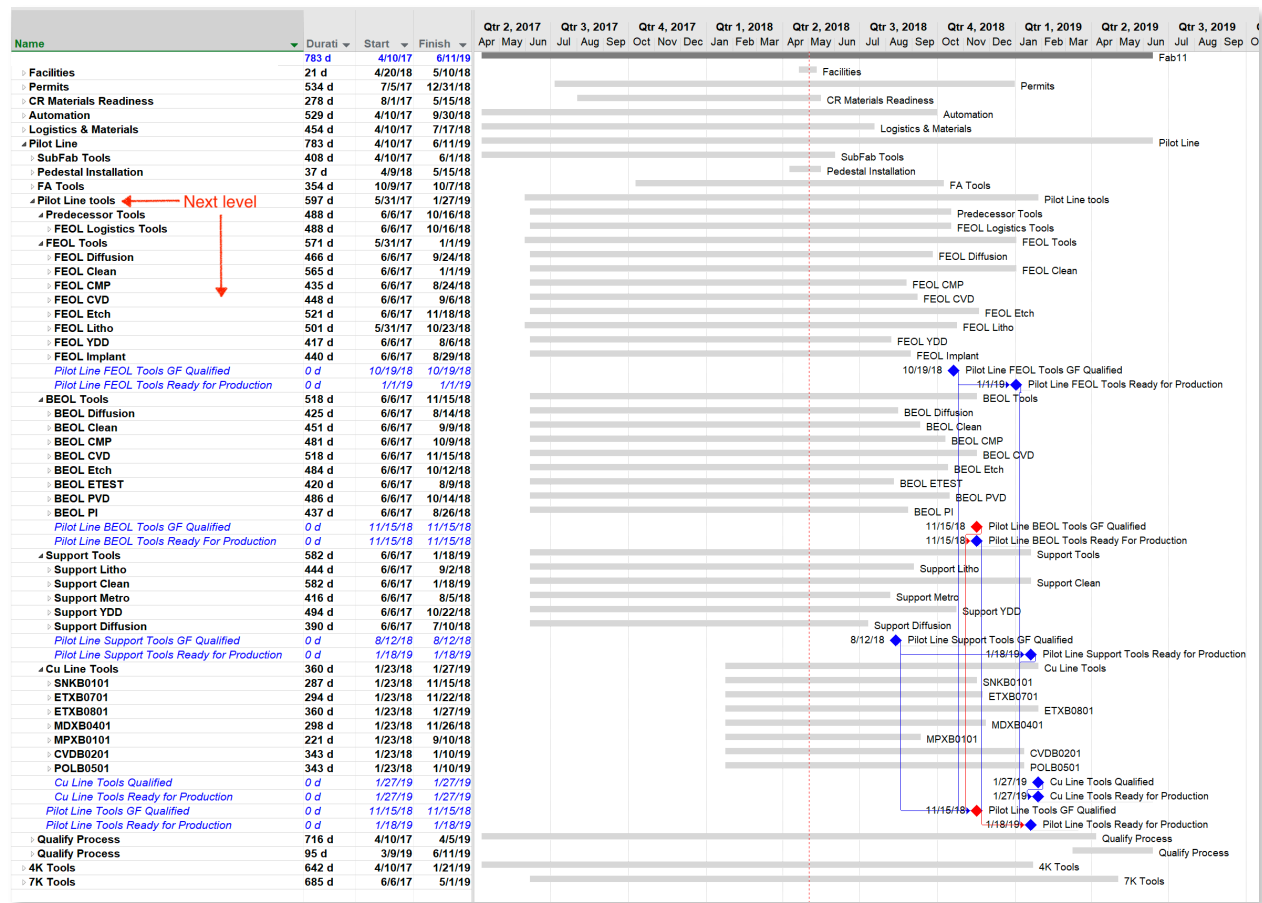
schedules “Touch” each other (or interface with each other). They are visually different from a regular milestone which allows us to filter and analyze them separately. The Touchpoints link directly to tasks in the FabX schedule, so as the facility/construction dates change, we can see how it impacts Micro-schedule. An example of this is Clean Room Ready linking directly to the tool move-in.

- Automation (AMHS), including IT
- Logistics & Materials, e.g. customs
- Subfab Tools
- Pilot Line Tools by major tool group (Procurement, Valuation, Refurbishment, Installation, Hookup and Qualification)
- FA Tools
- Process Qualification (Pipe-cleaner, learning cycles, Risk Start)
- Product Qualification (Qual lots)

The next level of detail can be seen below, where the schedule is structured around the hierarchy:

Ramp Step → Tool Group → Process Flow Step → Module → Tool

Example: Pilot Line → Pilot Line Tools → FEOL → CVD → CVDB0801

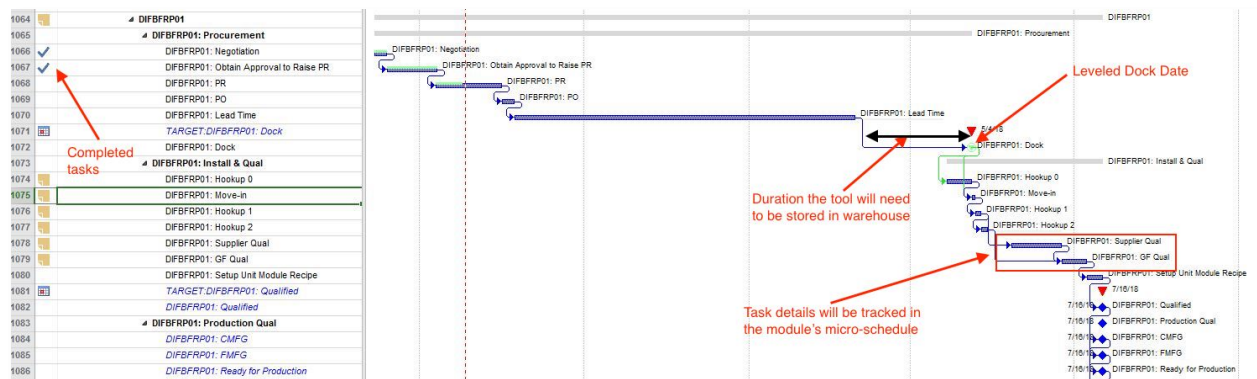


This structure more naturally supports a waterfall type of schedule, whilst making it easy to manage and navigate around the schedule quickly.

Drilling down one more level into the tools, we have:

1. Predecessor Tools: tools that are required to support the qualification of other tools, for the Pipe-cleaner or for Risk Start.
2. FEOL Tools: Front End Of Line Tools
3. BEOL Tool: Back End Of Line Tools
4. Support Tools: tools, by module, that are required to support the bring-up of the Pilot Line

Each of these are then broken down by each of the nine Process Modules (such as Etch, Clean, Litho, etc.) and then, at the lowest level, by specific tool. A tool template was used to quickly build out the schedule (discussed in more detail next). The image below is an example of a tool.



The annotations describe how to read a tool schedule. The red triangle (line 1081) is the date the tool needs to be qualified by in order to hit the ramp step date (in this case, the Risk Start date). In addition, the tool has a target date on the dock date (line 1071). As there are only 3 docks, and as tools come in varying sizes from multiple vendors - all of which are seen as constraints - it is necessary to tightly control (down to the day level) which a tool is moved in when. This is also set by IE. If a tool arrives later than the target dock date, it means it will miss its slot and potentially miss the ramp step date. If a tool arrives early (as in the example above), it means it will need to be stored in a warehouse.

The system thus identifies late tools in three ways. Tools that are late relative to the:

1. Target Dock Date date and the predicted Dock date (date provided by suppliers, based on Fab Owner need-dates)
2. Target Qualification Date date and the predicted Qualification date (driven by customer needs)
3. Target Ramp Step date and the predicted Ramp Step date (driven by customer needs)

As the schedule gets built-out to include additional Ramp Steps and different technologies, target dates will be set for the dock and qualification of the individual tools, typically determined by IE modeling and supplier commitments.

The FabX program management system is based on a unique system called Fast-Time-To-Market or FTTM. FTTM is based on the best practices of fast teams of delivering on schedule. This system was used in Fab8 in Malta, New York where they delivered First Silicon 2-weeks early with over 100,000 activities in their combined schedules..

Key Fast-Time-To-Market (FTTM) best practices adopted on the FabX project include:

- Targets dates are driven by the business need
- A realistic schedule is built, basing it on realistic estimates from the team (not top-down drive dictates)
- The FabX macro-schedule schedule is updated by a cross-functional team (a member from each organization) each week (includes progress updates and changes to the schedule)
- Bottleneck tools are identified and opportunities to accelerate (to close the gap between the target and predicted dates) are found
- The Management Team meets each week to explore strategic schedule pull-in opportunities
- Module-level daily schedule refreshes and Operation's meetings (update and pull-in)
- Schedule trends are tracked for Risk Start milestone and used as an early warning of potential problems to identify before-the-fact problems so action can be taken in advance of the failure
- Schedules and dashboard are presented and published each week using live data. All effort is made to use the live data and reduce the amount of "filtering" that typically goes on as data is passed up the corporate hierarchy

As the core of the schedule is based around the tools and hence the tool template , we will now describe this in more detail.

Tool Template

To aid in the quick development and future analysis of the schedule a “tool template” was developed. The tool template captures the complete life cycle of both new and existing (in the case of refurbished) tools; from procurement through to qualification (tool release to manufacturing). The templates for new tools and refurbished tools are slightly different, as will be discussed. The template maintains a standard flow and speeds up the process of construction a schedule. Every new tool and refurbished tool will look the same because of this template. The template has been refined over many months of user input from the various functions that use it.

Refurbished Tool

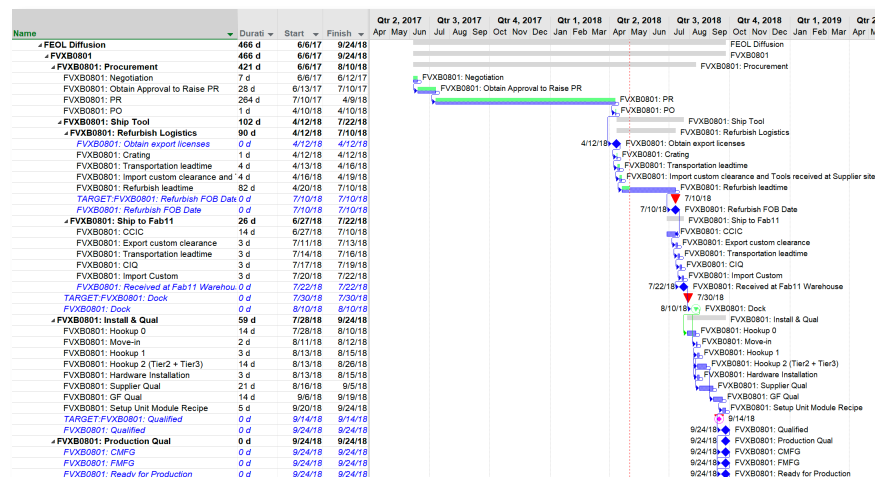
The structure of a refurbished tool is shown below. Each tool has a Tool ID (FVXB0801 in this example) and all tasks related to that tool are prefixed with the Tool ID. Form a high-level, there are three major sections to each tool:

1. Procurement
2. Install & Qual
3. Production Qual (not required for the Pilot Line)

Procurement is responsible from the initial negotiation through to tool delivery (dock). The Process Modules are responsible for Install & Qual, i.e. all tasks after the dock through to qualification and tool release.

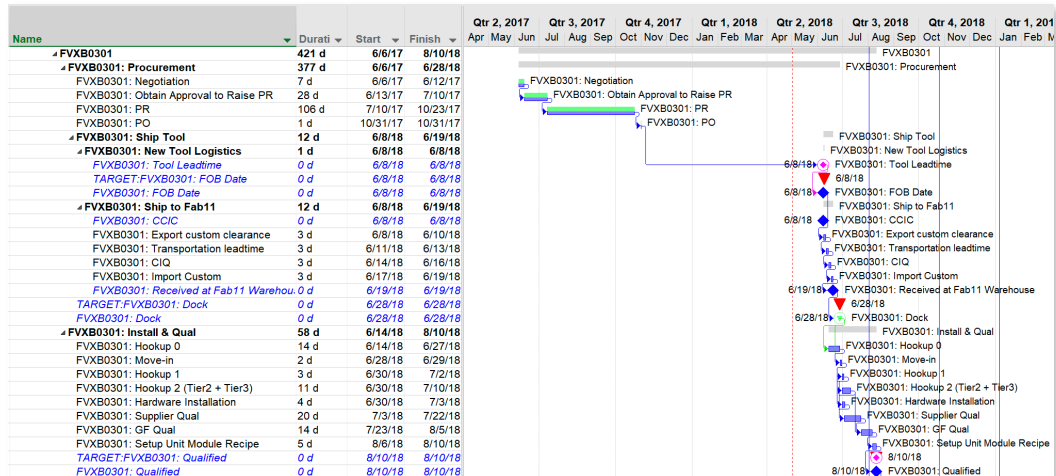
For a Refurbished Tool, additional tasks are needed in the template as refurbished tools require export licenses, transportation to the manufacturer for refurbishment, there’s a refurbishment lead time and then it has to ship to FabX. These additional tasks are captured under the “Refurbish Logistics” summary task in the template (see below).

Each tool, whether it’s a refurbished tool or a new tool, has three targets: a target FOB Date, a target Dock Date and a target Qualified Date. These target dates are depicted as red triangles in the schedule.



New Tool

The structure of a new tool is shown below. The only difference between a new tool and a refurbished tool is there are no refurbished tasks under the Logistics summary task. Once a PO is placed directly with the vendor, there is a certain lead time before when the tool is docked (arrives).



Whether a refurbished tool or a new tool, the tool “lead time” is depicted in one of two different ways. When the lead time is estimated, it is represented as a task with a specific duration. Each week, the estimated lead time is updated if there are any changes to the deliver due date. When a supplier has committed to a delivery date (typically after the PO has been issued), the duration is converted to a milestone which is set at the committed delivery date (like in the example shown above). This allows us too easily differentiate the difference between committed dates (milestone with a date) and estimated dates (lead time tasks with duration).

Tool Fields

Dedicated fields (in Microsoft Project) are used to manage the import, export and analysis of the tools. If a new tool is added to the schedule, then it is important these fields are completed (when importing, they are set automatically). These fields are:

- Module Owner (Text1) - required for all tasks in the template
- Activity Owner (Text2) - required for each task and milestone (summary tasks can be omitted)
- Update Group (Text3) - required for all tasks in the template
- Ramp Step (Text26) - required only for the tool’s top-level task, e.g. FVXB0301
- Module (Text28) - required for all tasks in the template
- OEM (Text29) - required for all tasks in the template
- Tool Source (Text30) - required for all tasks in the template and should be set to:

- "Discrete" meaning a new tool
- "Promos" meaning an existing tool that will get refurbished at the vendor
- "Promos Onsite" meaning an existing tool that will get refurbished onsite

Module Micro-schedule Structure

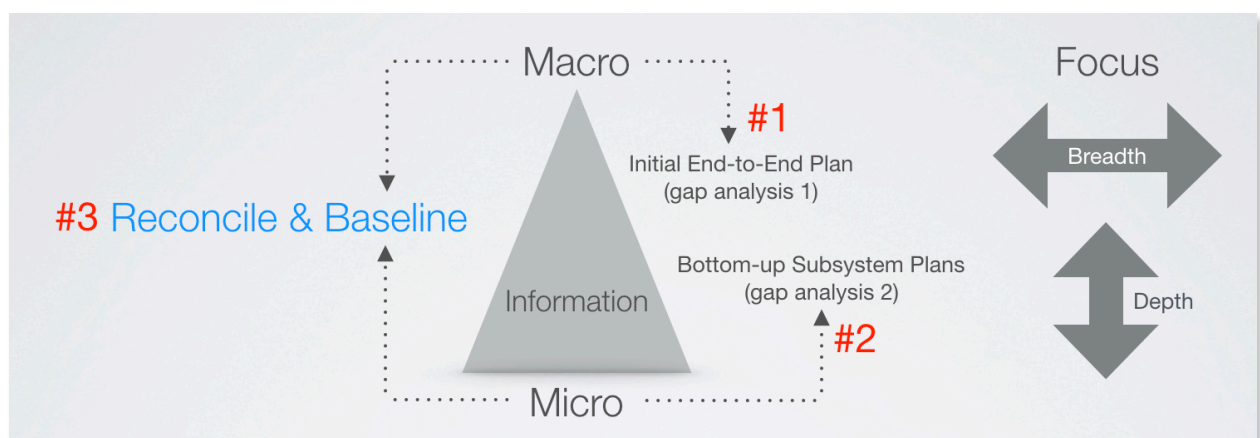
As described earlier, the FabX macro-schedule contains all high-level (macro) tasks to provide us with a critical path to Risk Start. The critical path is the longest contiguous path of linked tasks to the end of the project, which then determines the end date of the project. However, in reality there are a lot of detailed tasks within each macro task. For example, a 3-week Supplier Qual task could have 16 subtasks, each down to the 1-day duration level.

The obvious solution is to add these tasks to the FabX macro-schedule. However, there are a number of potential problems with this approach:

- The number of tasks would explode (even at the macro level there are already >6,500 tasks for just the Pilot Line)
- The ownership, management and maintenance of the schedule would all fall on the PM, which would be an overload
- When we analyze the critical path to look for pull-in opportunities, we wouldn't be able to "see the forest for the trees" - we would lose the bigger picture and get lost in the detail

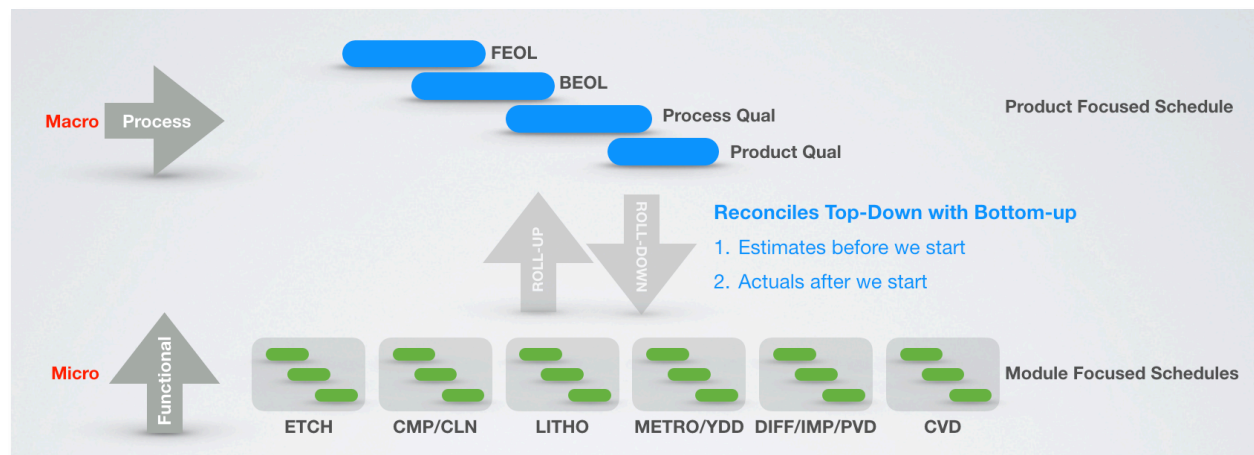
To overcome these problems, we adopted a method called Macro-micro Roll-up (see [Macro-micro Roll-up](#)). Here, the detail (micro) tasks to the macro tasks are managed and tracked in a separate schedule called a micro-schedule. The macro-schedule and the micro-schedule are related in such a way that the lowest level of the macro-schedule matches the top-level of the micro-schedule. For example, a Supplier Qual task in the FabX macro-schedule (the lowest level) would be a top-level (summary) task in the micro-schedule which would contain multiple subtasks. The Macro-micro Roll-up function synchronizes the macro and micro-schedules.

Thus, the FabX macro-schedule gives us the breadth without a lot of detail, whereas the micro-schedules give us the detail. This is graphically depicted below.



The only question that now remains is how to best partition the FabX macro-schedule into multiple micro-schedules. It is very common when managing a fab to think of tools and ownership

by module and are managed by a module manager and a module team. There are nine modules in FabX, so the FabX program management system consists of ten schedules: the FabX macro-schedule and 9¹ Module micro-schedules²: PVD, Metrology, Litho, Implant, Etch, Diffusion, CVD, CMP and Clean. The image below shows this graphically.



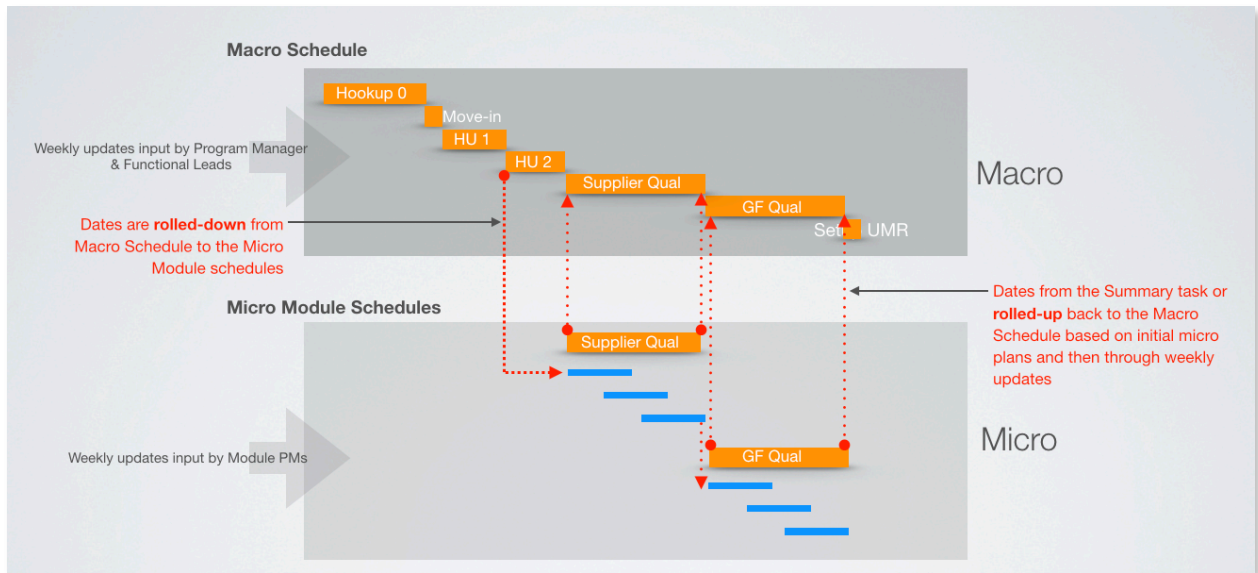
The macro-schedule is thus a cross-functional schedule where tasks flow as a lateral process, the way a project would naturally flow. It allows the management team to keep their eye on the big picture and look for strategic pull-ins. It is owned by the program management team (PMO). The micro-schedules are functional schedules (by module). They are independently managed by the module managers (created, tracked and reported) without any direct interaction needed with the FabX macro-schedule.

The system permits top-down, bottom-up reconciliation where changes in the FabX macro-schedule is reported down to the Module micro-schedules and the detail from the Module micro-schedules work is reported back up to the FabX macro-schedule. When "rolling-up" all Module micro-schedules, we can see changes at the micro levels in terms of how they impact on the FabX macro-schedule. The FabX macro-schedule is then not overloaded with excessive amounts of detail, while the Module micro-schedules can be opened and drilled down when micro analysis is required.

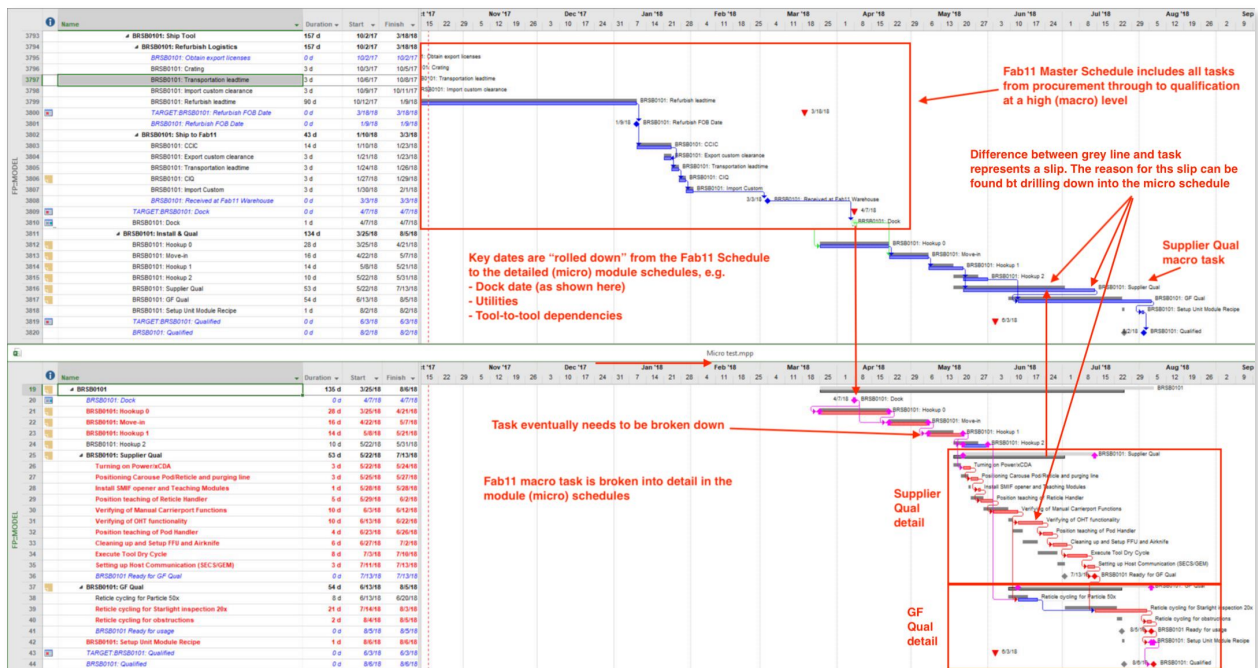
This synchronization can be seen graphically (following) where the bottom level of the FabX macro-schedule is the top level of the Module micro-schedule. One level's micro is the next level's macro - and so on and also in reverse. Key dates from the FabX macro-schedule, such as the dock date and utilities, are "rolled down" down to Touchpoints in the Module micro-schedules. Together with

¹ ETEST and FA tools are managed in the FabX macro-schedule

² Another reason for choosing the Macro-micro Roll-up approach is we are not constrained by the structure of the FabX macro-schedule. Thus, whereas the FabX macro-schedule is an integrated cross-functional schedule, the Module micro-schedules are essentially functional schedules. The Macro-micro Roll-up function keeps everything synchronized.



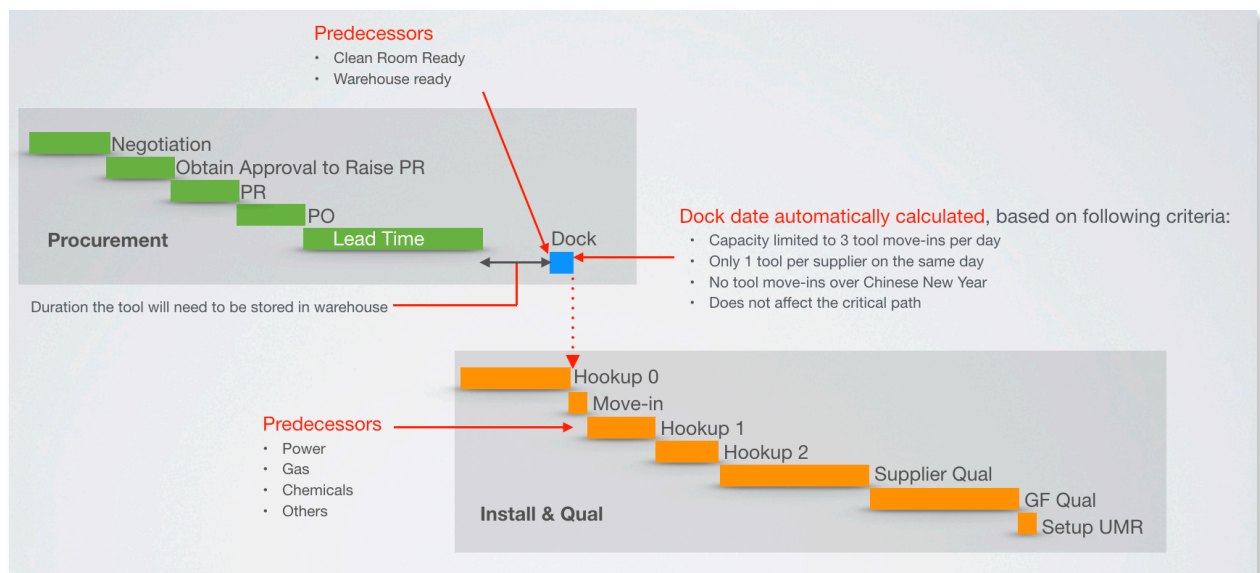
the detailed (blue) subtasks in the Module micro-schedule, the changes are “Rolled-up” back to the FabX macro-schedule.



The next image shows how this works using a real example. The FabX macro-schedule is depicted in the upper half and contains two roll-up tasks that are part of tool BRSB0101 from the Litho micro-schedule: Supplier Qual and Fab Owner Qual. Note the start date of the Fab Owner Qual task is offset from the Supplier Qual finish date. The Litho micro-schedule (in the lower half) contains the detail tasks for these two tasks.

At the FabX macro-schedule level, the Supplier Qual takes 53 days and the Fab Owner Qual starts about half-way through. The Litho micro-schedule answers questions why it takes 53 days and what is driving the start date of Fab Owner qual.

The next image shows how Touchpoints work in the context of the Macro-micro Roll-up. The procurement activities (in green) exist only in the FabX macro-schedule. The orange tasks however exist in both the FabX macro-schedule as macro tasks and as summary tasks (with subtasks) in the Module micro-schedules. The Touchpoint is the point where both schedules “touch”, i.e. are dependent on each other. This date therefore needs to be rolled down to the Module micro-schedule.



The main difference between the roll-up and roll-down, is dates from the FabX macro schedule are rolled-down whereas durations from the Module micro-schedules are rolled-up.

Setting up the Macro-Micro Roll-up for FabX

Setting up the Macro-micro Roll-up for FabX is relatively straightforward and mostly automated (the details on how to do this are discussed in the section Macro-micro Roll-up). The list below

shows those tasks that are typically rolled-up and rolled-down. Note that these are typical examples. The exact information is module dependent.

Roll Down from the FabX macro-schedule to the Module micro-schedules

- All key facility dates (building, utilities, gases and chemicals)
- Environmental Impact Report (EIA)
- Clean Room Materials Ready
- Support Tools and Accessories (e.g. chiller)
- Logistics Infrastructure Ready
- Dangerous Goods (Cl2, CO2, SiCL4, CH4)
- Subfab Ready
- Predecessor tools (relevant for the module) qualified
- Dock dates (both actual date and Target date)
- FOB dates (Refurbished and new tool)

Roll Up from a Module micro-schedule to the FabX macro-schedule

- Hookup 0
- Move-in
- Hookup 1
- Hookup 2 (Tier2 + Tier3)
- Hardware Installation
- Supplier Qual
- Fab Owner Qual
- Setup Unit Module Recipe