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Accelerating Advanced Backend Automation through Smart Application of Frontend GEM 300 Standards

SEMICON® WEST HYBRID

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We must also credit developers of the software tools highlighted herein…

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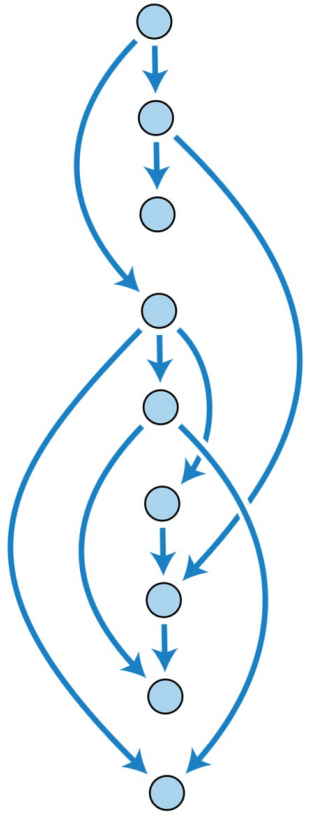
Outline

- Background and motivation
- Solution approach and key innovations
- Current status
- Conclusions and next steps



Background and motivation

Background and motivation

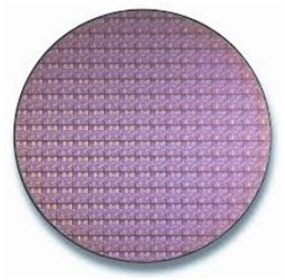
- Increasing emphasis on quality and productivity by OSATs and IDM backend facilities
- Tighter integration of wafer fab and backend as number and complexity of product form factors increase
- Requirements for single device traceability in several critical market segments
- Specific drivers include
  - Demands by consumer product customers for equipment data to support quality and supply chain optimization initiatives
  - Need better event/status data to support automated calculation of OEE and other KPIs
  - Broader deployment of multivariate FDC, which requires more trace data parameters than operational monitoring
  - Actual feedback control based on backend metrology (e.g., saw performance optimization using kerf data) and inspection data

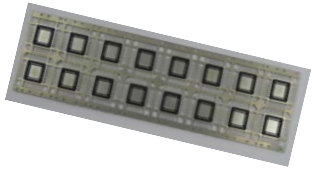
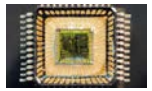
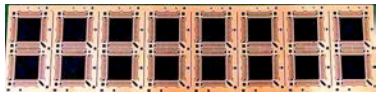
Backend automation challenges
In contrast to wafer fabrication

- Multiple material transformations
- Flow shop manufacturing operations
- High product variety and velocity
- Significant manual intervention
- Complex unit product traceability
- Low equipment cost and automation budget
- Supplier un-familiarity with SEMI Standards
- Handling multiple data source types/protocols

Backend material/carrier forms
and related processes

- Incoming wafer
  - Wafer mounting
- Mounted wafer
  - Saw
- Strip (lead frame)
  - Die bond
  - Wire bond
  - Mold
  - Cure
  - Trim and form
  - Plating
  - Mark
- Individual packages
  - Final test and burn-in
  - Pack and ship



Related backend automation topics

- Handling multiple carrier types
  - FOUPs, magazines, trays, carts
  - And carriers of carriers of …
- Augmenting equipment data with human input
  - Equipment fault codes, operator actions, settings selection
- Managing WIP buffers in “open corrals”
- Consumable/durable handling and management
- Cost-effective integration of “simple” equipment
- Compliance testing for non-standard requirements
- Educating the supplier base

Solution approach and key innovations

Key innovation #1

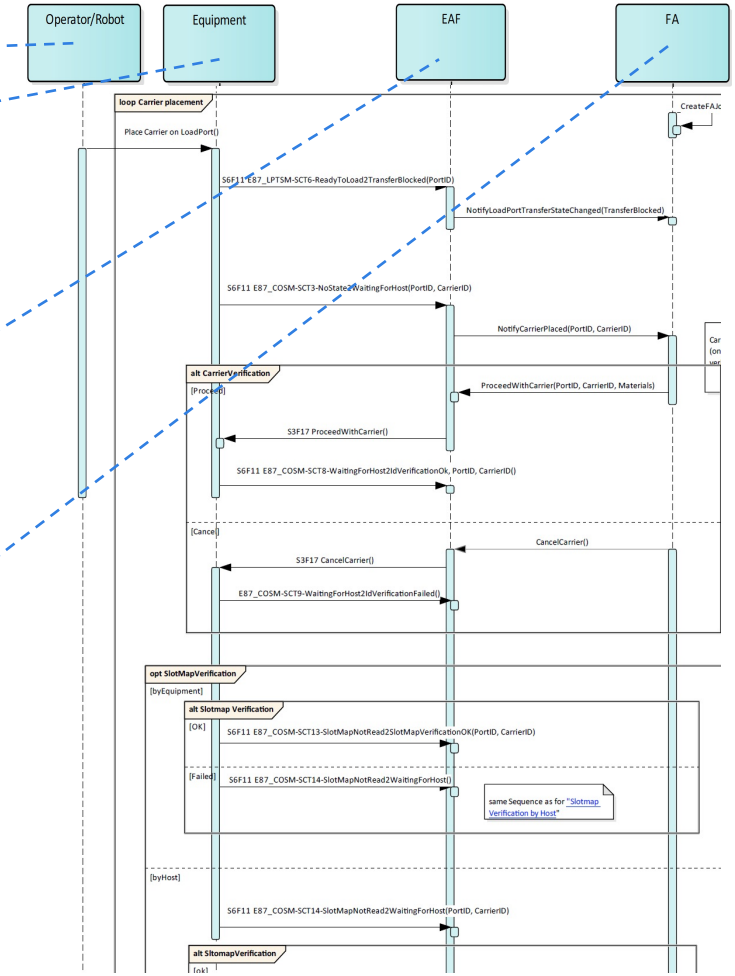
Explicit backend operational scenarios

- Several backend equipment purchase specs already list applicable GEM 300 automation standards, but provide little additional guidance
- Infineon has gone well beyond this to define a “Target Equipment Integration Sequence” in its latest Tool Operation Specification for Backend (TOS BE)
- Scope includes detailed interactions among system elements using the following GEM 300 standards:
  - Object services (E39)
  - Job creation, execution, and tracking (E40, E94)
  - Carrier placement, verification, and removal (E87)
  - Substrate processing and tracking (E90)
  - Substrate mapping and full traceability support (E142)
  - Consumable and durable handling (New!)
- Also enables automated validation by standard GEM protocol test software

Target Equipment Integration Sequence

Expression: Ladder diagram of system communication partners

- Operator/robot/AGV
  - Load/unload material
  - [Occasionally] provide input
- Equipment
  - Perform process operations
  - Communicate principally with EAF component
- EAF – Equipment Automation Framework
  - Implement SEMI Standards and Integration Sequence
  - Provide bridge to generic Backend Factory Host
  - May include site-specific automation logic
- FA/EA – Factory/Equipment Automation
  - Backend Factory Host system(s)
  - Provide MES, OEE, APC, and other application functions



Segment of Ladder Diagram with all communication partners

Integration Sequence diagram/spec excerpts

FOUP, MultiDimensional and Nested Carriers

- Backend material transformations require different carrier types
- This complicates content verification AND device traceability
- Equipment handling all carrier types must support E87 Carrier Management, including content (slotmap, etc.) verification
- FOUPs have the familiar list of slot IDs
- Multidimensional carriers include a location spec for each substrate (x, y, z position)
- Nested carriers (and their content maps) have inner carriers at specified locations, which in turn have their own content maps
- The number of slots, positions, and inner carriers varies by product type and must be configurable

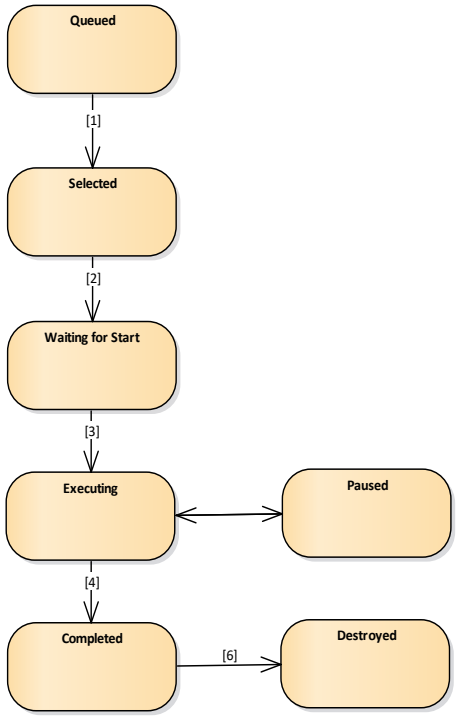
```
S3,F17 H->E
<L [5]
 <U4 [1] 5>%comment: DATAID
 <A [18] 'ProceedWithCarrier'>
 <A [5] 'Carrier123'>
 <U1 [1] 1>
 <L [4]
  <L [2]
   <A [8] 'Capacity'>
   <U1 [1] 1000>
  >
  <L [2]
   <A [5] 'Usage'>
   <A [7] 'PRODUCT'>
  >
  <L [2]
   <A [14] 'SubstrateCount'>
   <U1 [1] 2>
  >

  <L [2]
   <A [16] 'NestedContentMap'>
   <L [1]
    <L [3]
     <A 'WT1'> %comment: InnerCarrier name
     <I2 [3] 0 0 1> %comment: Position array of x y z (DataItem CPOS) in parent carrier
     <L [2]
      <L [3]
       <A [10] 'Substrate1'>  %comment: SubstID
       <A [6] 'Lot123'>  %comment: LotID
       <I4 [3] 1 1 0>  %comment: Position array of x y z (DataItem CPOS) in parent carrier
      >

      <L [3]
       <A [10] 'Substrate2'>  %comment: SubstID
       <A [6] 'Lot123'>  %comment: LotID
       <I4 [3] 1 2 0 > %comment: Position array of x y z (DataItem CPOS) in parent carrier
      >

    >
   >
  >
 >
```

ProceedWithCarrier #2 Nested Content Map

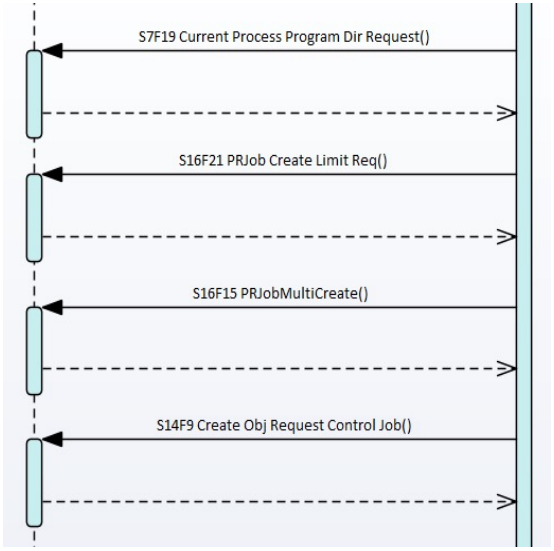
Integration Sequence diagram/spec excerpts

Process/Control Job creation and execution tracking

- Required Process/Control Job states and transitions are specified
- However, some equipment types have no concept of a “job”
  - They merely execute a fixed operation sequence, perhaps with some settings selected by product type
  - Regardless, these processes still require full automation support in the Integration Sequence



Process Job States

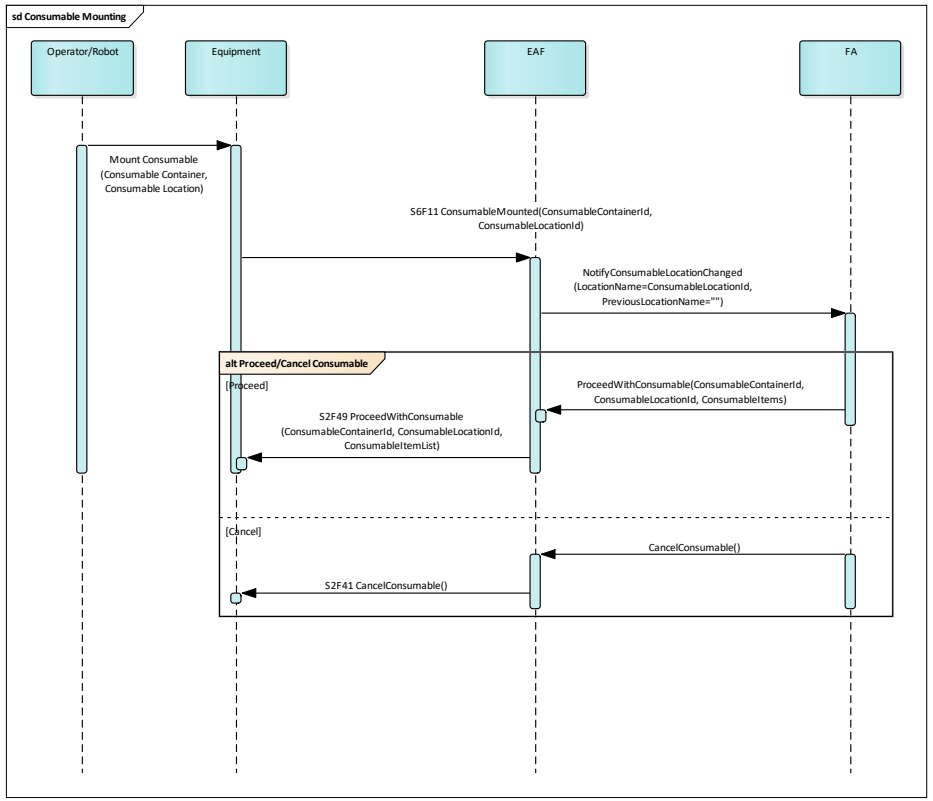


Control and Process Job Setup

Integration Sequence diagram/spec excerpts

Consumable/durable handling

- New traceability requirements now include keeping track of consumable materials and durable components used for each device
  - Manual record keeping is too error prone to satisfy this requirement
- Consumables are materials that are consumed during manufacturing of a product, and which are directly identified with that product
  - Examples include glue, mold compounds, wires, etc.
- Durables are tools or parts which are mounted on the equipment and used in the manufacturing process
  - Examples include feeders, grippers, adapters, etc.
- Mounting, Verification, Consumption, and Unmounting must be supported
- Required variables, events, and commands are described in the appendices

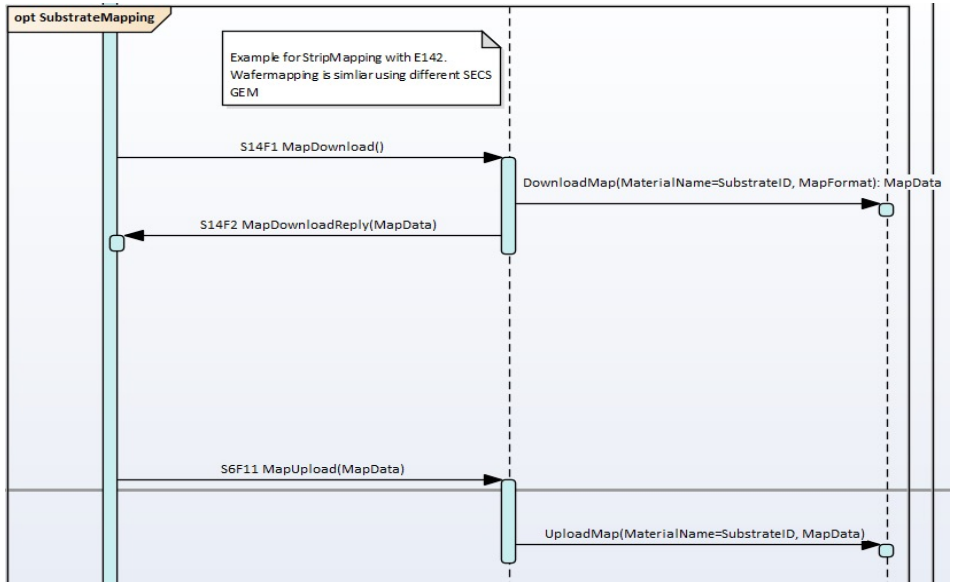


Consumable Mounting and Verification

Integration Sequence diagram/spec excerpts

Substrate map download/upload (E142)

- For equipment types that have substrate mapping functionality, the map download and upload sequence is required
- Substrate types in this context may include wafer, strip, or tray
- Specific data items that must be included in the map are detailed in the appendices
- Note that the E142 schema has recently been updated to accommodate much more traceability information

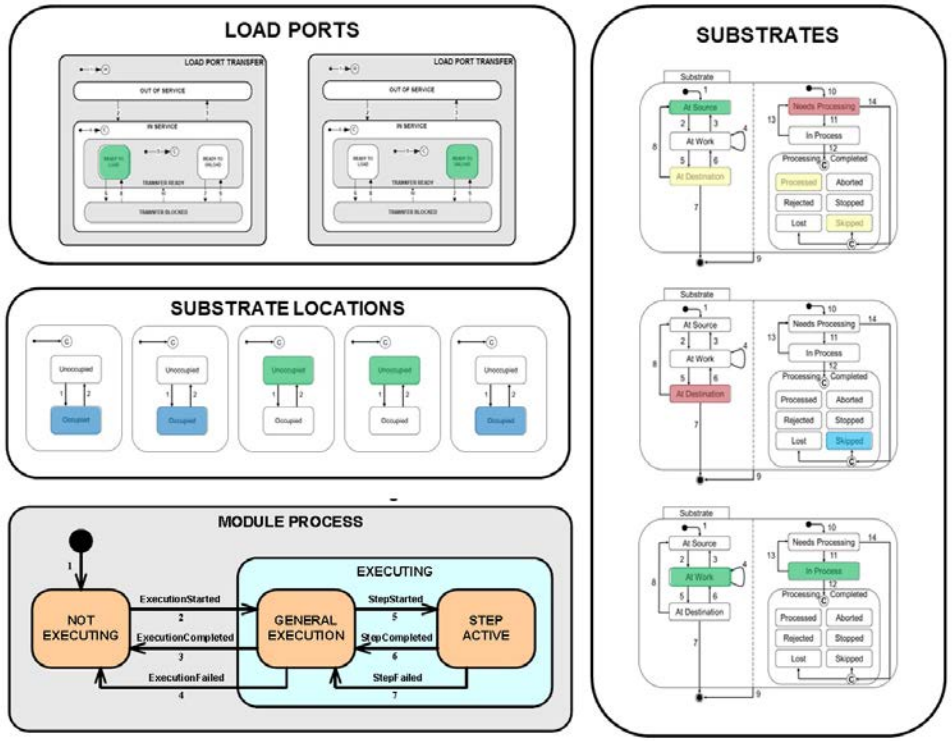


Substrate Map Download and Upload

Key innovation #2

Adaptation of mature GEM/GEM 300 automation standards

- Specific messages/objects from the GEM/GEM 300 are woven together in the Target Equipment Integration Sequence
- This concept was a major success factor in the definition and use of SEMI's automation standards at the 300mm wafer size transition in the mid-90s
- This results in significant reuse of existing factory and equipment connectivity software
- This also enables equipment suppliers unfamiliar with SEMI Standards to implement a subset of GEM 300
- The only modifications made to the standard GEM 300 message set were those needed to support carrier/tray ID and content verification

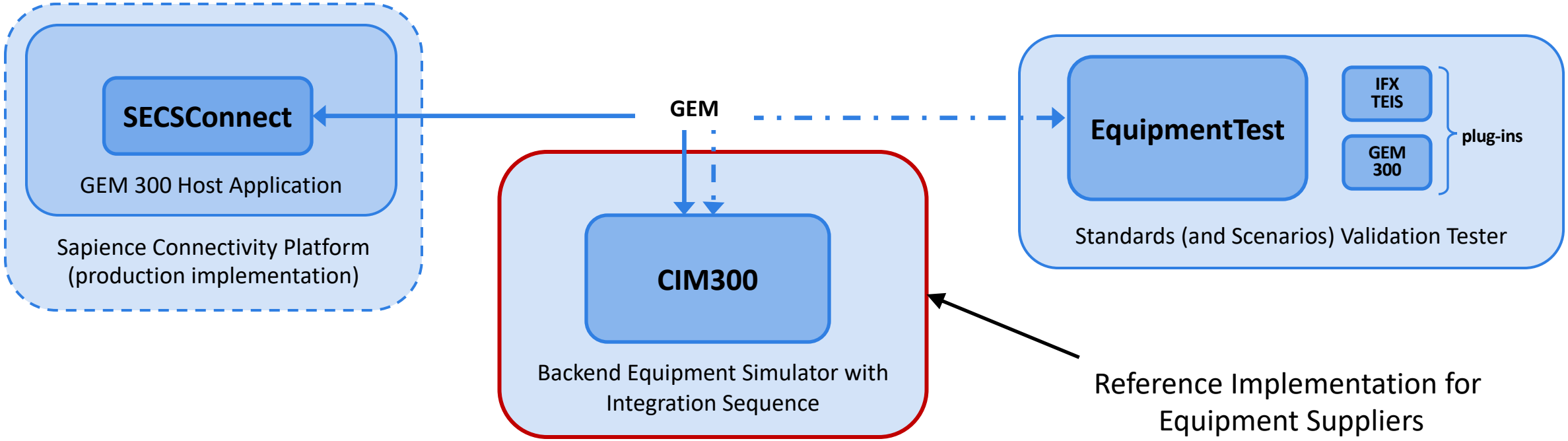


Synchronized View of Multiple GEM 300 State Machines

Key innovation #3

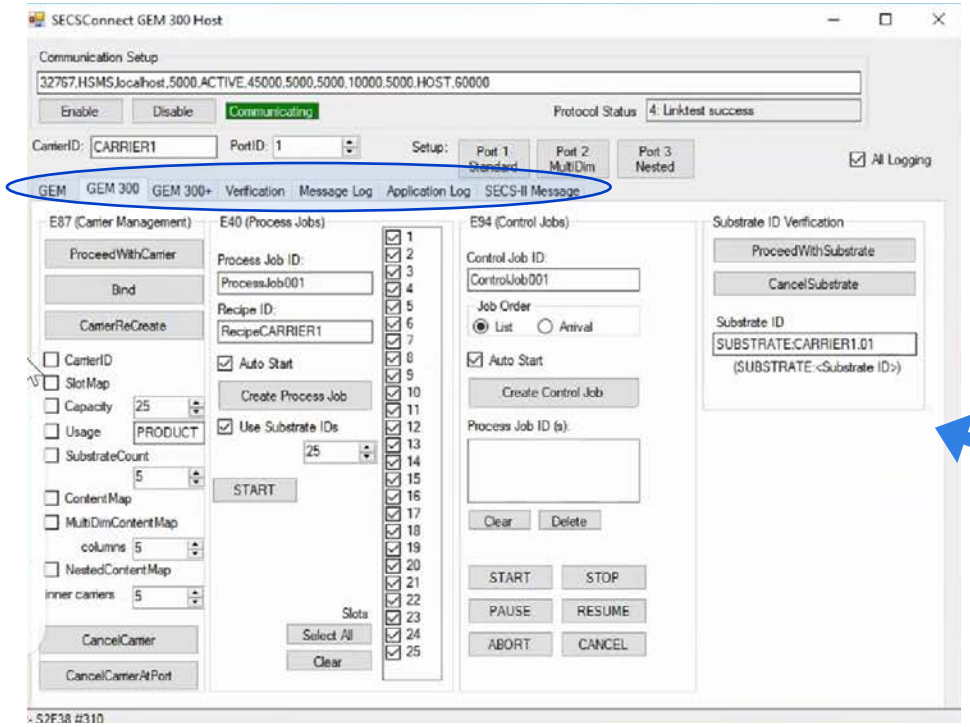
Reference implementation and validation test software

- Entire Target Equipment Integration Sequence is realized in a sample application suite
  - Equipment simulator, communication partner utility (Robot, EAF, FA/EA), validation tester plug-ins
  - Brings the specification to life
  - Accelerates equipment supplier development process to incorporate the sequence in their products



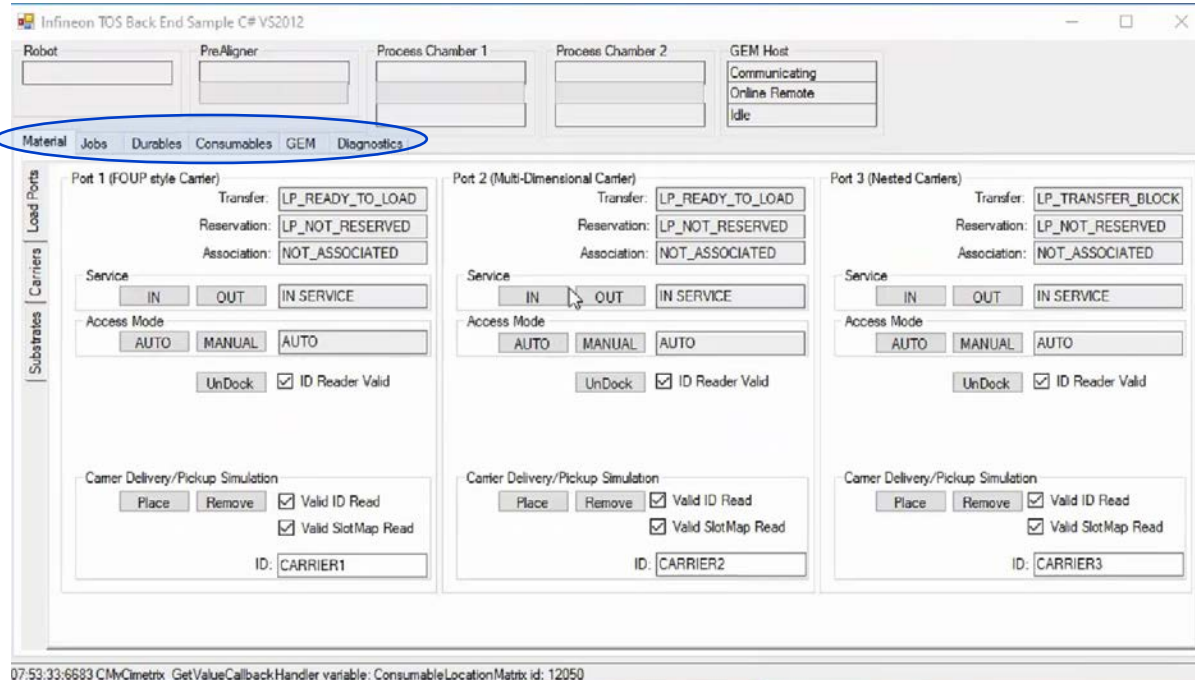
Backend equipment simulator and sample factory host

Incorporate GEM 300 libraries to fully implement Integration Sequence



GEM 300 Host Application (Factory System)

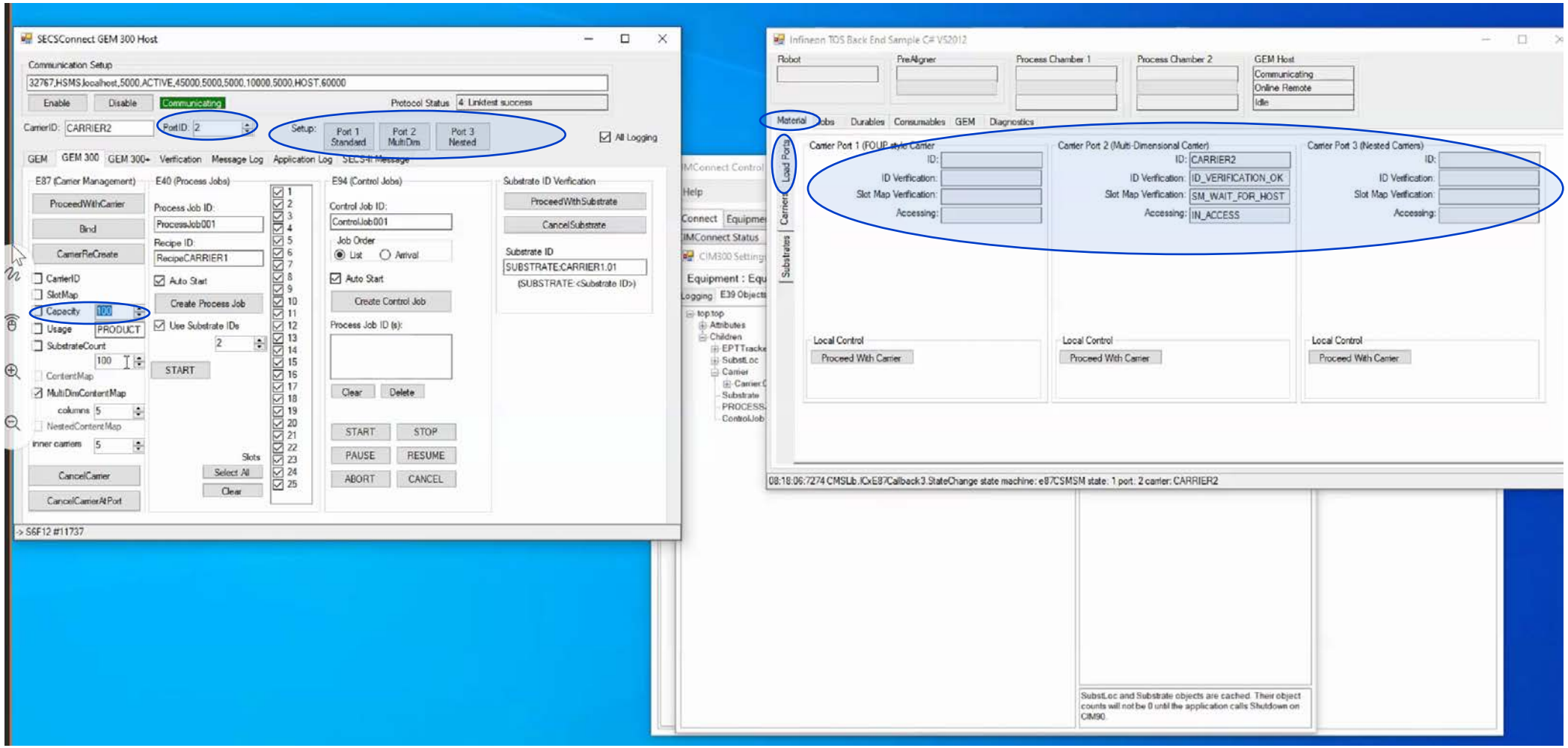
GEM



Backend Equipment Simulator

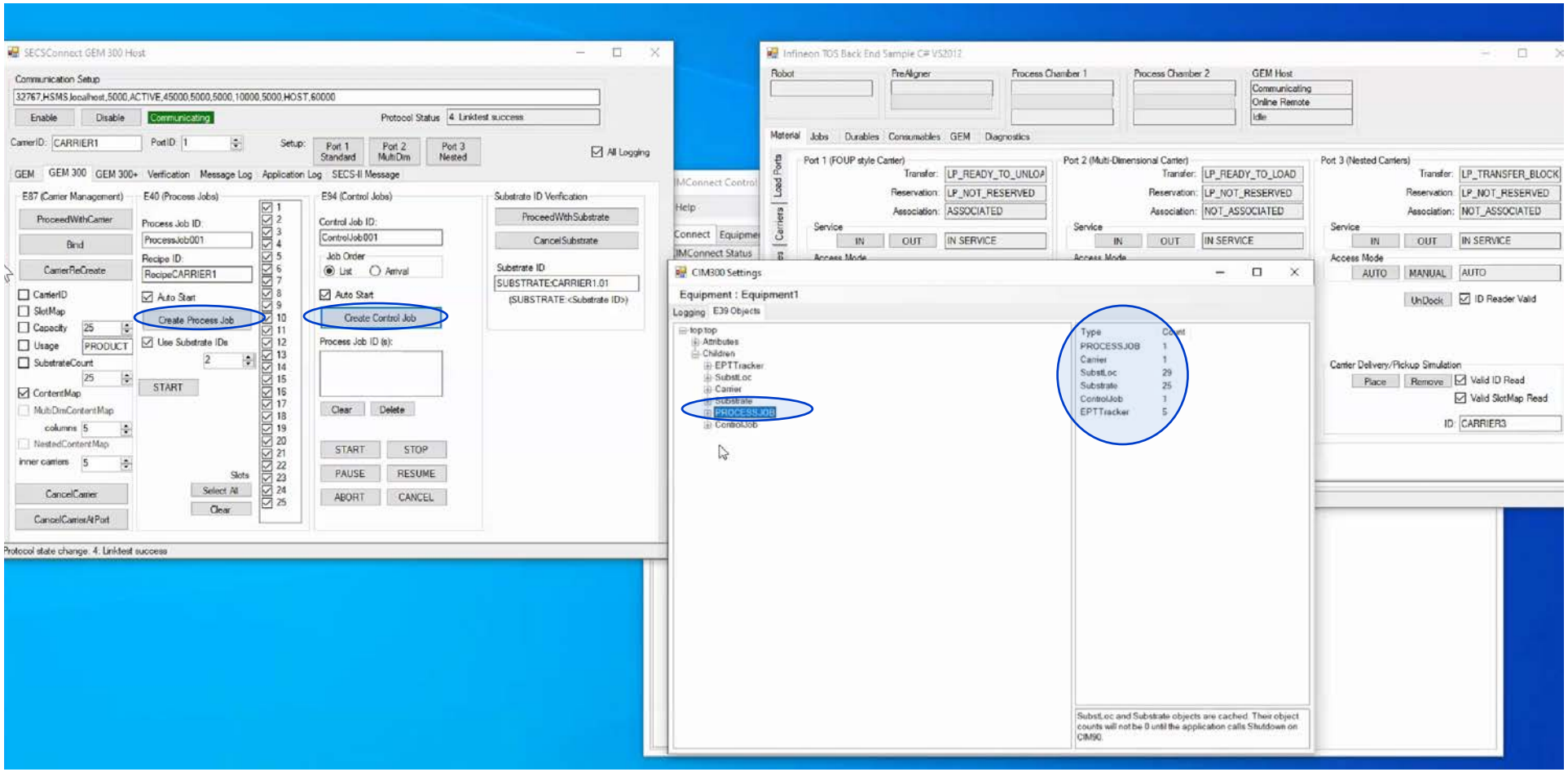
Backend equipment simulator

Carrier management (FOUP style, MultiDimensional, Nested)



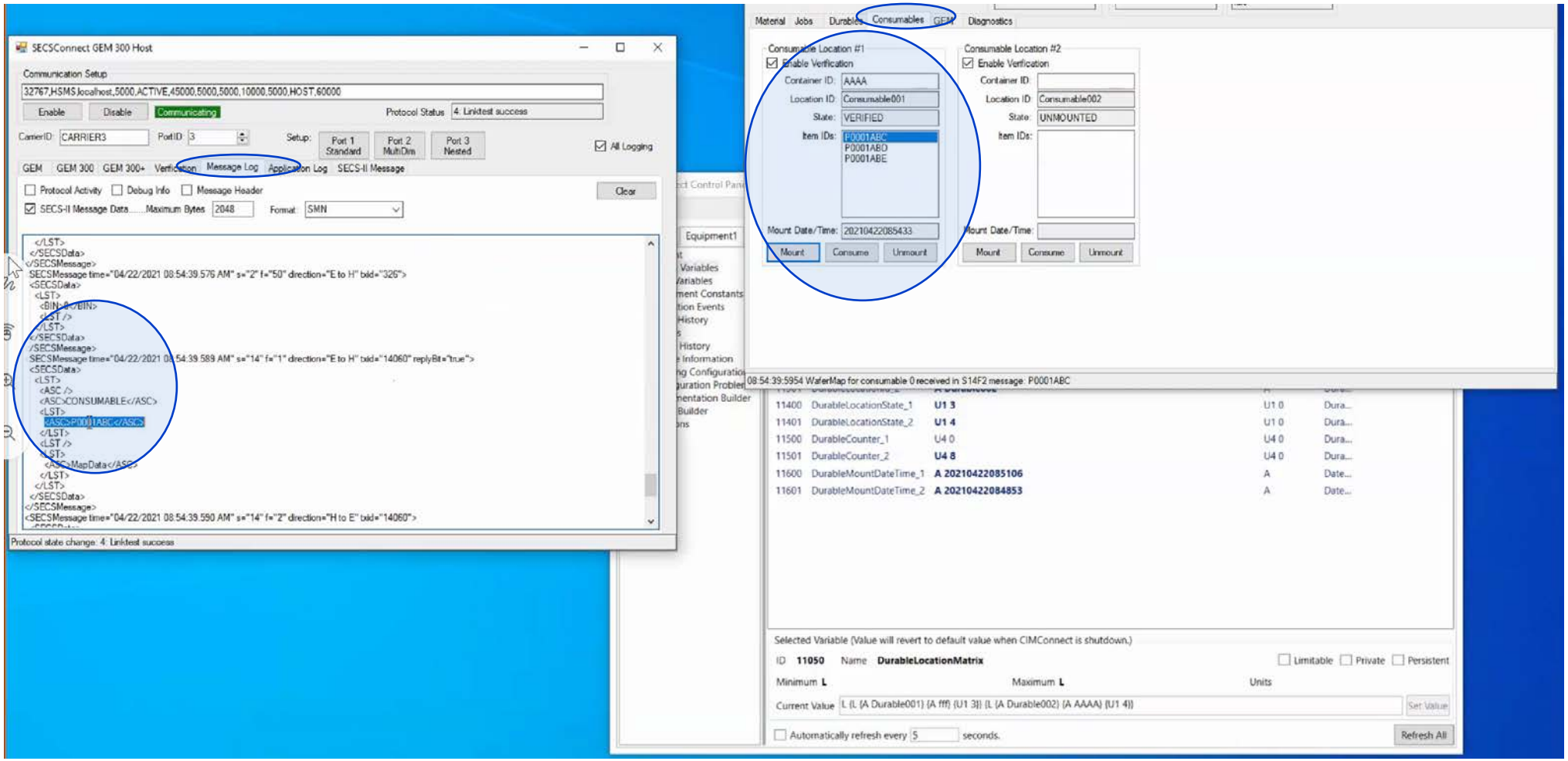
Backend equipment simulator

Job control



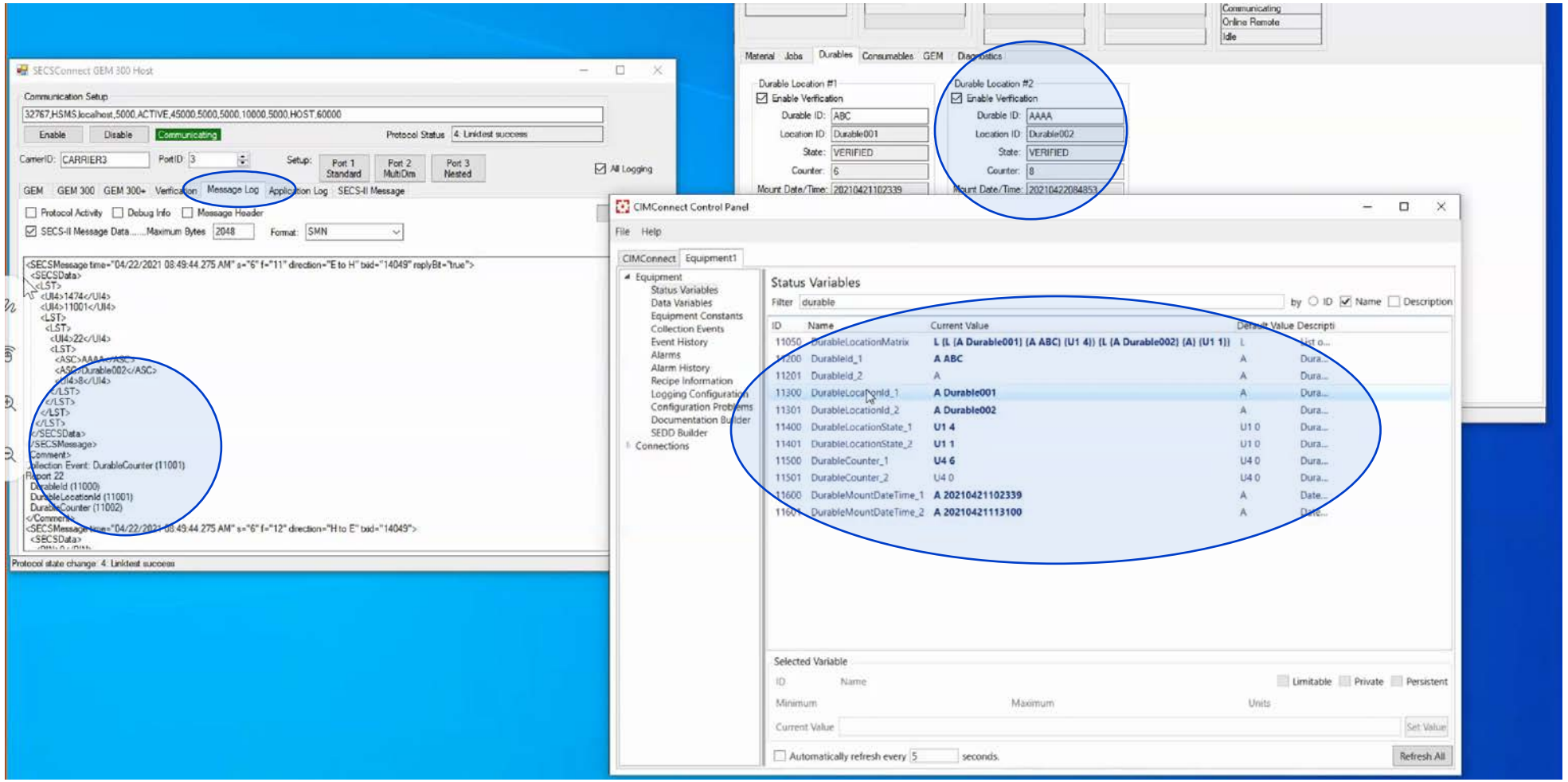
Backend equipment simulator

Consumable handling



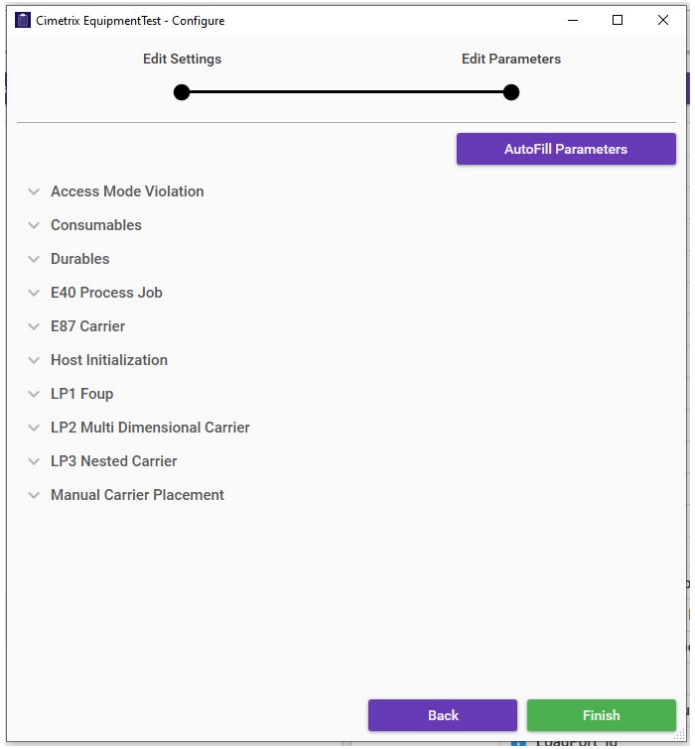
Backend equipment simulator

Durable handling

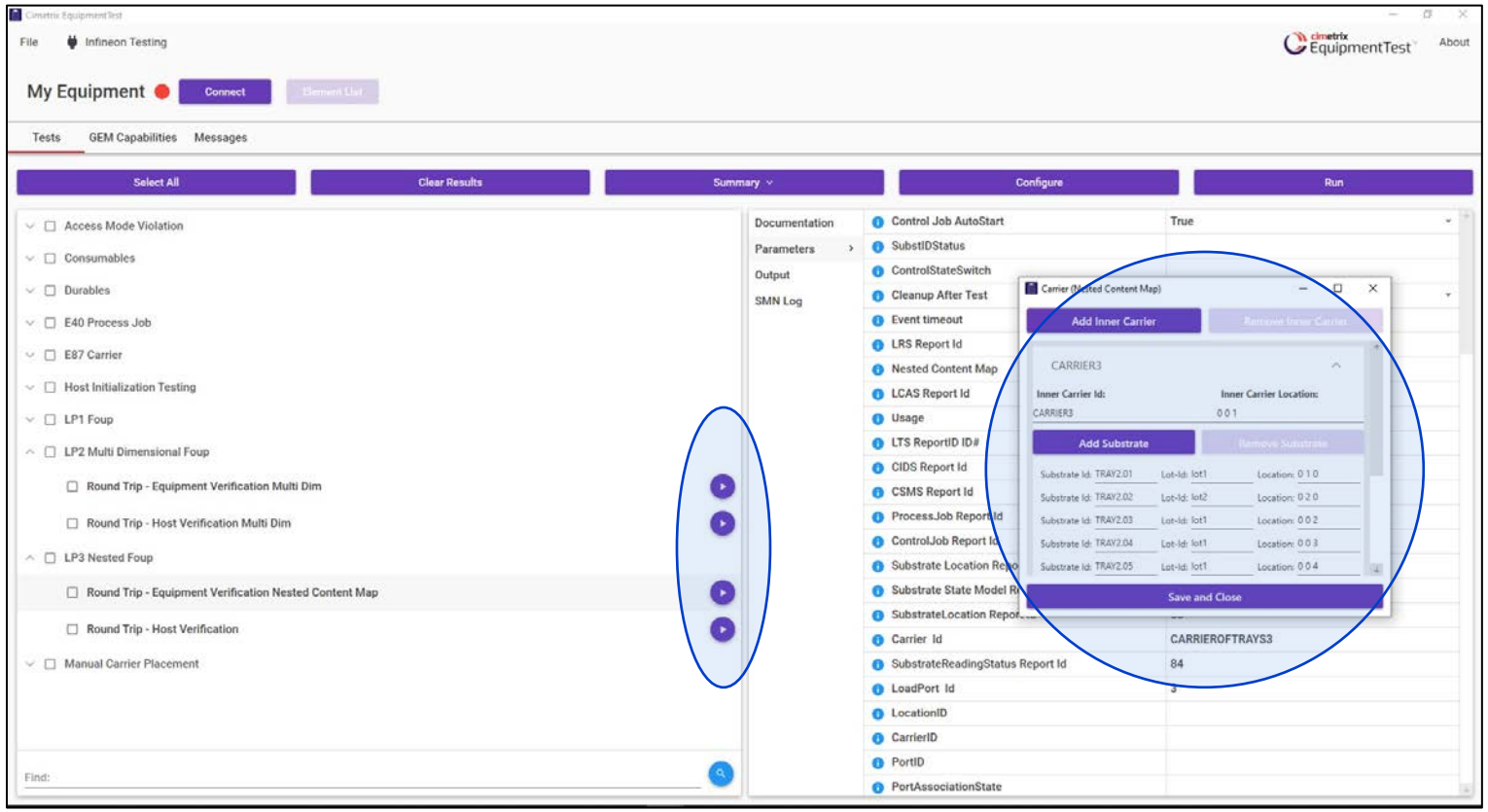


Validation tester plug-in

Extends GEM 300 compliance tests to include Integration Sequence items



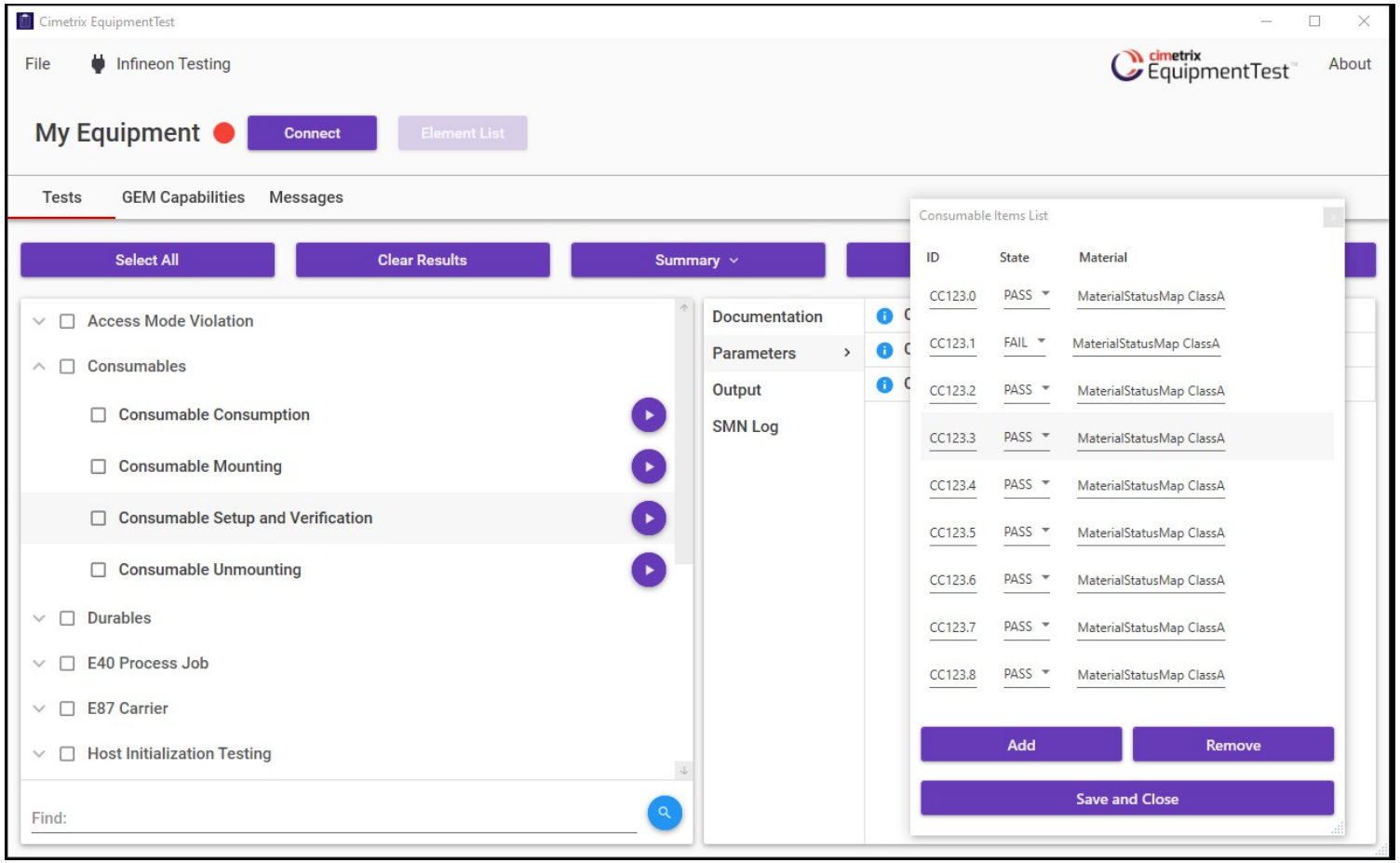
Scope of Integration Sequence Plug-in
(Configuration Settings Screen)



Nested Carrier Content Map Verification Sequence Tests

Validation tester plug-in

Consumable handling example



Consumable Handling Sequence Tests

Key innovation #4

Integration Sequence document transfer to SEMI Standards community

Advanced Backend Factory Integration Task Force (ABFI TF)

- Charter
  - "To explore, evaluate, discuss, and formulate consensus-based specifications that, through voluntary compliance, will enhance assembly and test for semiconductor manufacturing"
  - Operating principle: ensure that any new backend standards are consistent with the existing body of connectivity standards *and* leverage as much of the current SEMI standards as possible, especially GEM / GEM 300
- Focus to date
  - Updating E142 (Substrate Mapping) to support single device traceability (tracking raw materials and process materials, adding new substrate types)
  - Identifying needed updates in existing standards (GEM, GEM 300, EPT, etc.)
- Members (companies)
  - Energetic mix of major device makers, equipment and software suppliers

Current status, Conclusions, Next steps

Current status

- Target Equipment Integration Sequence fully defined
  - And included in latest Tool Operation Specification for Backend (TOS BE V 2.4.4)
- First equipment simulator reference implementation complete
  - Including matching host utility application and Validation Tester plug-ins
- Stakeholder training material development underway
- Technology transfer process has now begun (this public presentation!)

Conclusions

- Wherever possible use proven standards – don’t invent new ones
- It is encouraging to see that with minimal interpretation and adaptation many of the GEM 300 operational scenario elements can be used for backend equipment
- Several companies are already taking this approach, so the stage is set for deeper collaboration
- This is low-hanging fruit – if we truly want to accelerate the pace of cost-effective backend automation, adopting GEM-based technology is the best way to go

Next steps

- Prepare technology transfer package for SEMI Standards (in process)
- Present material to SEMI Advanced Backend Integration Task Force (done)
- Present at major industry events (e.g., SEMICON West !)
- Host webinars to demonstrate reference implementation software
- Gather, review, and incorporate feedback into key artifacts
- Update ABFI standards roadmap
- Incorporate new features into our standard equipment, factory, and validation commercial products
- Promote to backend equipment/system suppliers

Questions and Answers

Thank You