

A11

Application Code Coverage Testing Improve Testing of Your Applications

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Agenda

- What is Code Coverage?
 - Goals/Questions addressed by code coverage
 - What is not code coverage?
- Types of Code Coverage Reports
- Creating the Code Coverage Environment
 - Demonstration
- Code Coverage in Projects in IMS
 - Demonstration
- Cross Reference Database
- Apar Regression Testing using Code Coverage
 - Demonstration

What is Code Coverage?

■ Code Coverage

- Application Testing Collection (ATC)
 - ▶ Provided by IBM Lexington
 - ▶ GA product for external and internal customers
- Identifies lines of code covered by testcases
- Creates reports on MVS
 - ▶ Summary: show %'s of modules covered
 - ▶ LOC statement results (branches, non execution, etc.)
 - ▶ Reports are parsed and sent via FTP to web server

Goals For Code Coverage

■ New Version Lineitem Coverage

- Broadly saturate coverage of new code
- Ensure testcase bucket is thorough and not repetitive
- Provide process to enhance testcase bucket

■ Apar Regression Testing

- Reduce Apar turnaround time/PE rate
- Shorten test cycle by reducing number of testcases in each test
- Verify Apars LOC are hit before delivery to customers

■ Testcase-to-Module Cross Reference Database

- Allow coders to build test environments using real testcases
- Apar recreations are easier
- Determine Apar Regression test bucket from database

■ No Changes to Any Testcases

What Code Coverage is NOT?

■ Code Coverage is NOT:

→ A replacement for unit testing

▶ Proper Testing includes:

- ✓ Boundary conditions
- ✓ Timing conditions
- ✓ Impossible conditions
- ✓ Variations on data
- ✓ Stress conditions
- ✓ Code coverage analysis

→ A solution for all types of problems (ex. missing code)

→ A replacement for Native or Stress testing

■ But... Code Coverage could help here, too!

OS/390 Code Coverage Products

■ IBM

- Application Testing Collection (ATC)
- Used for our project

■ InCert Examiner

- Coverage for Cobol applications

■ Compuware Xpediter (+ Coverage)

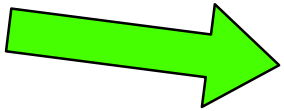
- Xpediter Debugger collects coverage data for single runs of Cobol application

■ McCabe Coverage

- Collects coverage data for single runs of Cobol application

Agenda

- What is Code Coverage?
 - Goals/Questions addressed by code coverage
 - What is not code coverage?
- **Types of Code Coverage Reports**
- Creating the Code Coverage Environment
- Code Coverage in Projects in IMS
- Cross Reference Database
- Apar Regression Testing using Code Coverage



Code Coverage Reports

■ Change Module Analysis

- Determine coverage of specific lines of changed code
- Application: Apars, new modules, changed modules

■ Missing Sequence Analysis

- Find consecutive sequences of code that are not executed
- Application: New releases, new modules, changed modules

■ Testcase Coverage

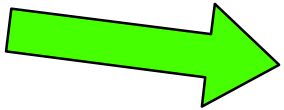
- Show coverage for individual or groups of testcases
- Application: New releases, new modules, changed modules, Apars

■ Build Worklist for Testing

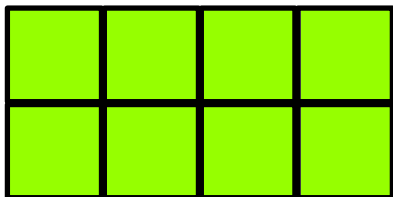
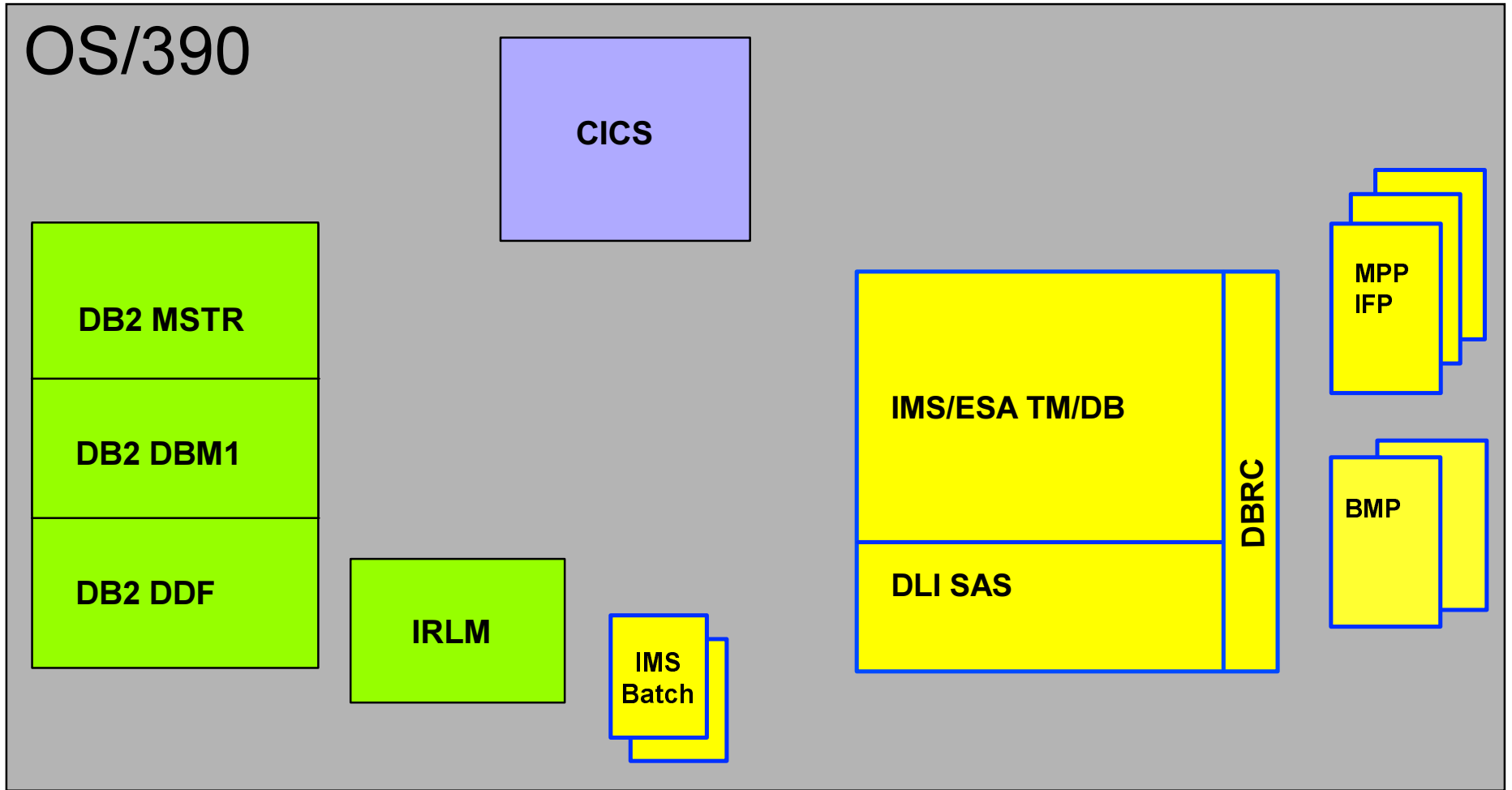
- Create list of testcases to cover a specific set of modules
- Application: New releases, new modules, changed modules, Apars

Agenda

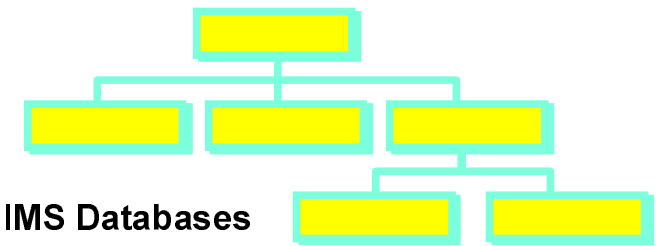
- What is Code Coverage?
 - Goals/Questions addressed by code coverage
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- Code Coverage in Projects in IMS
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ATC Code Coverage - Environment



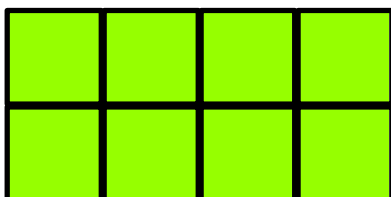
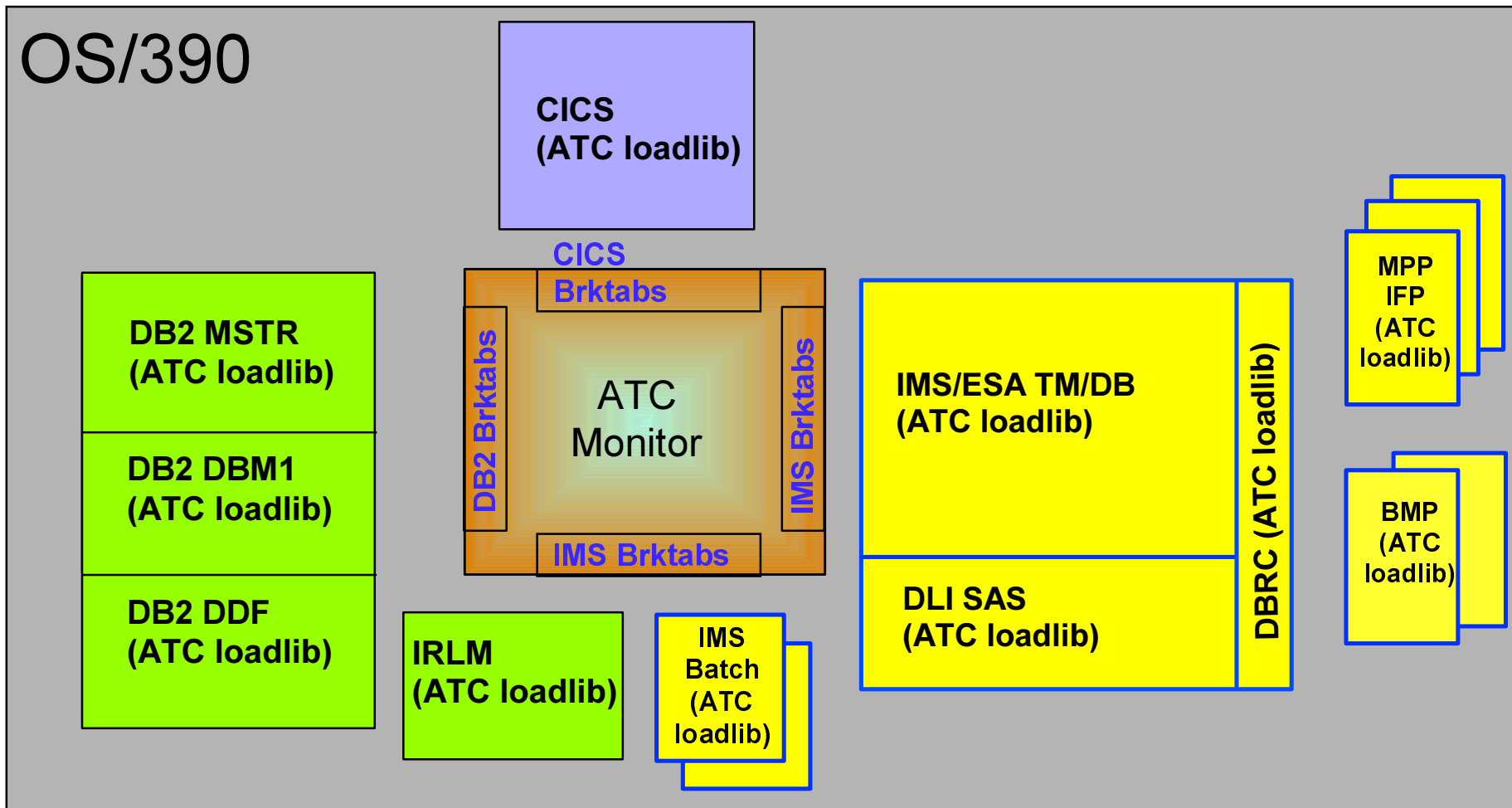
DB2 Tables



IMS Databases



ATC Code Coverage - Environment



DB2 Tables

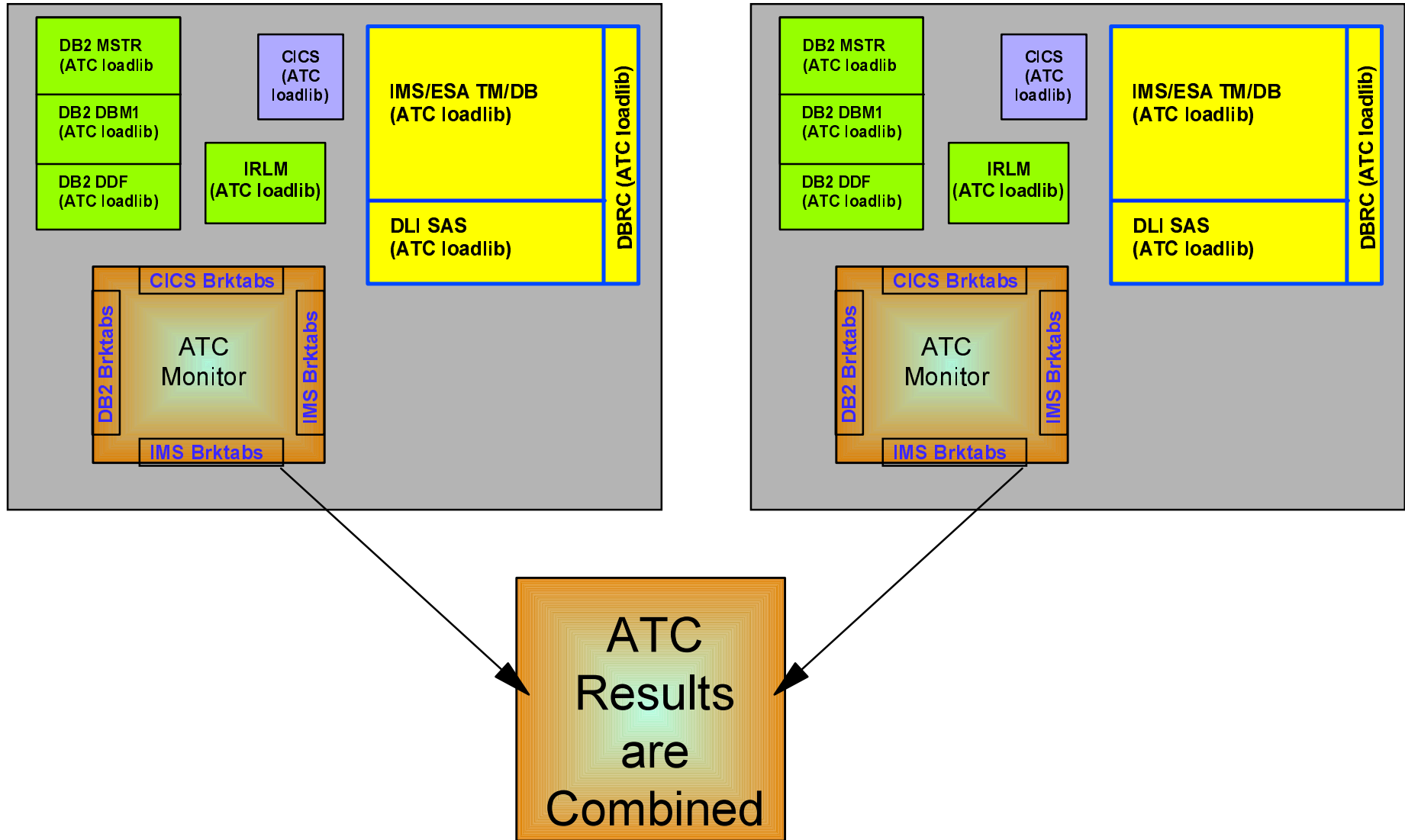


IMS Databases

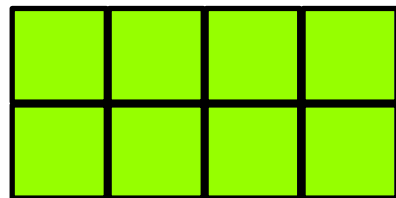
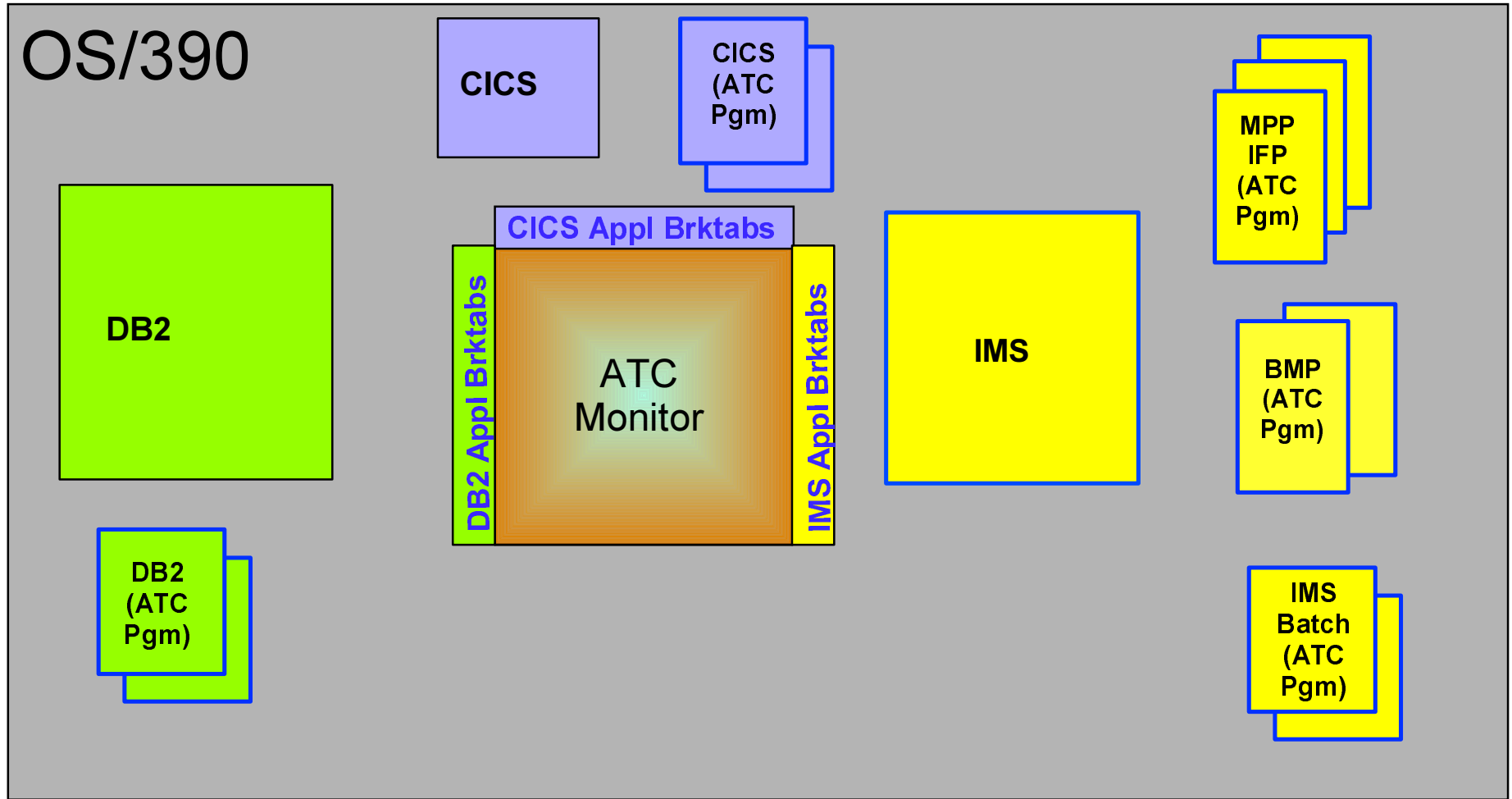


ATC Code Coverage - Environment

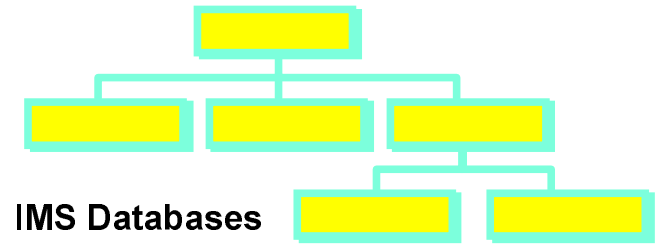
Parallel Sysplex Environment



Code Coverage - Customer Appls

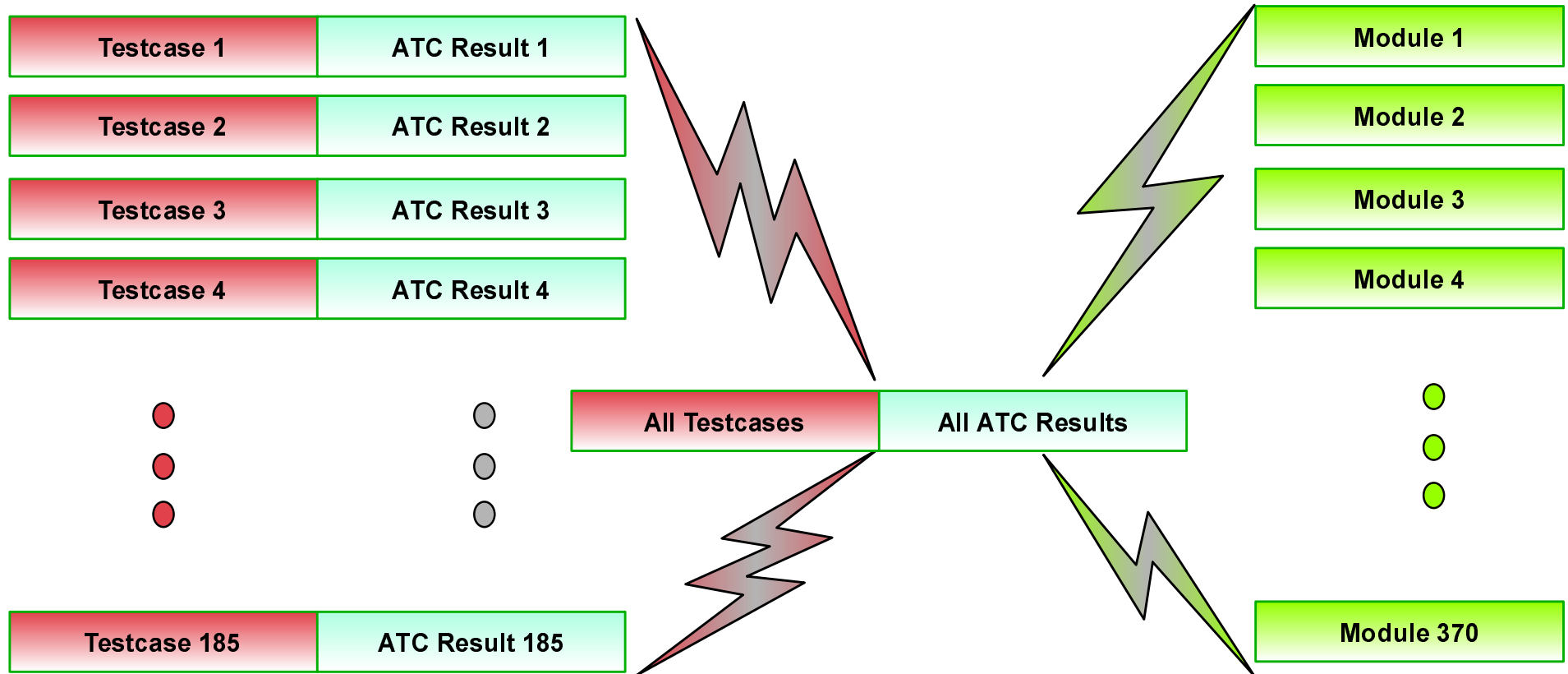


DB2 Tables



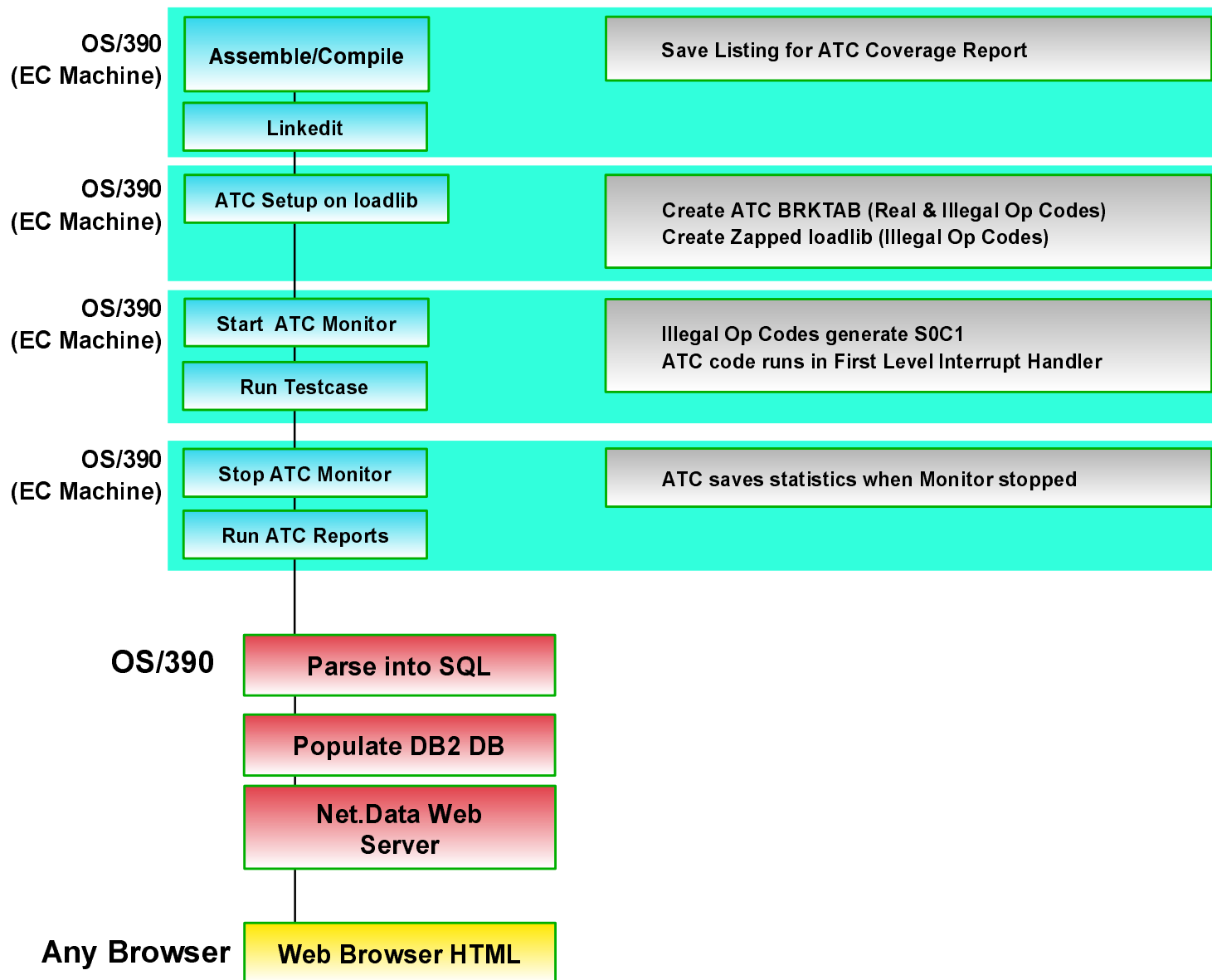
IMS Databases

Combining Code Coverage Results

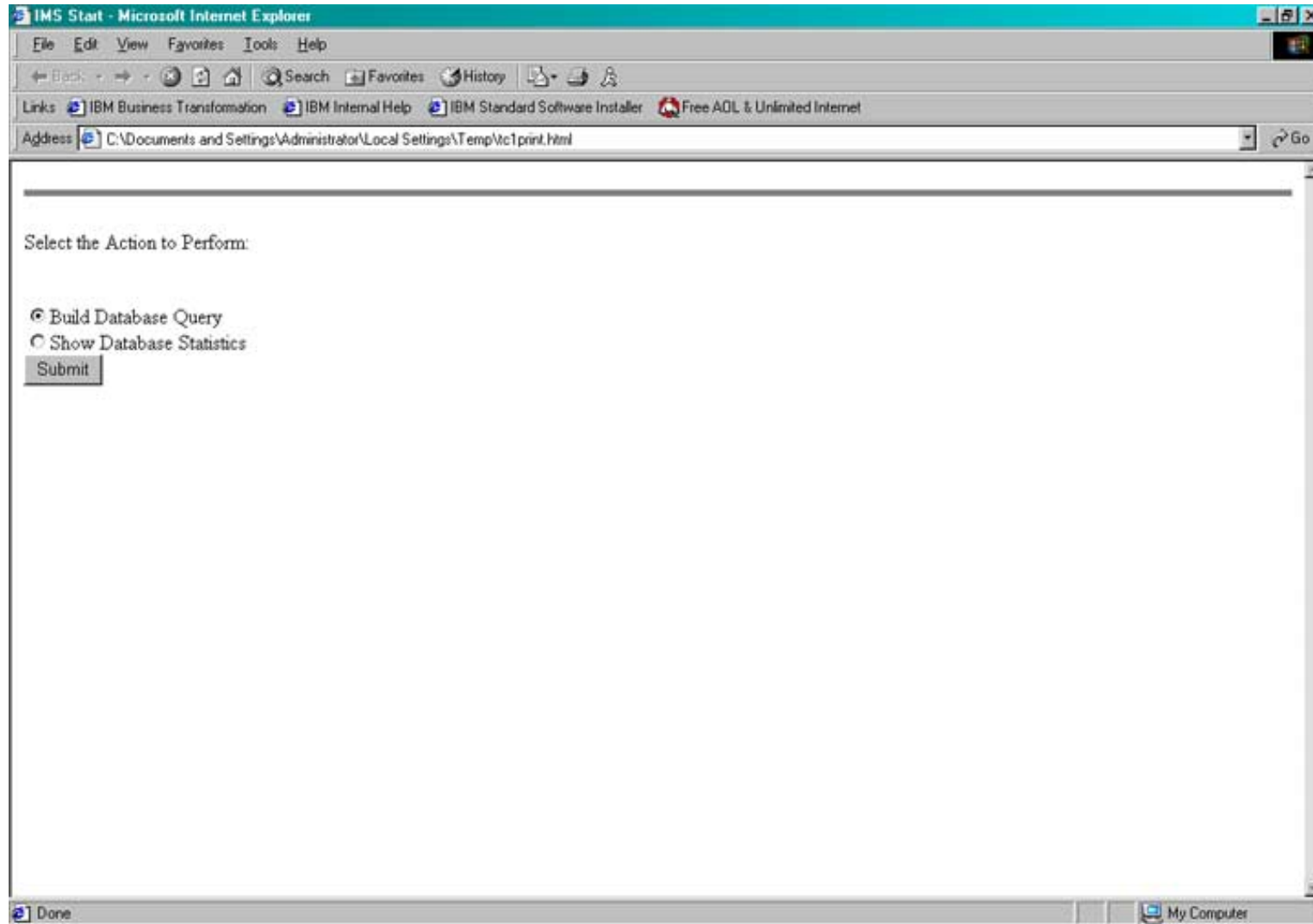


Combined Testcase Results are Mapped to Modules

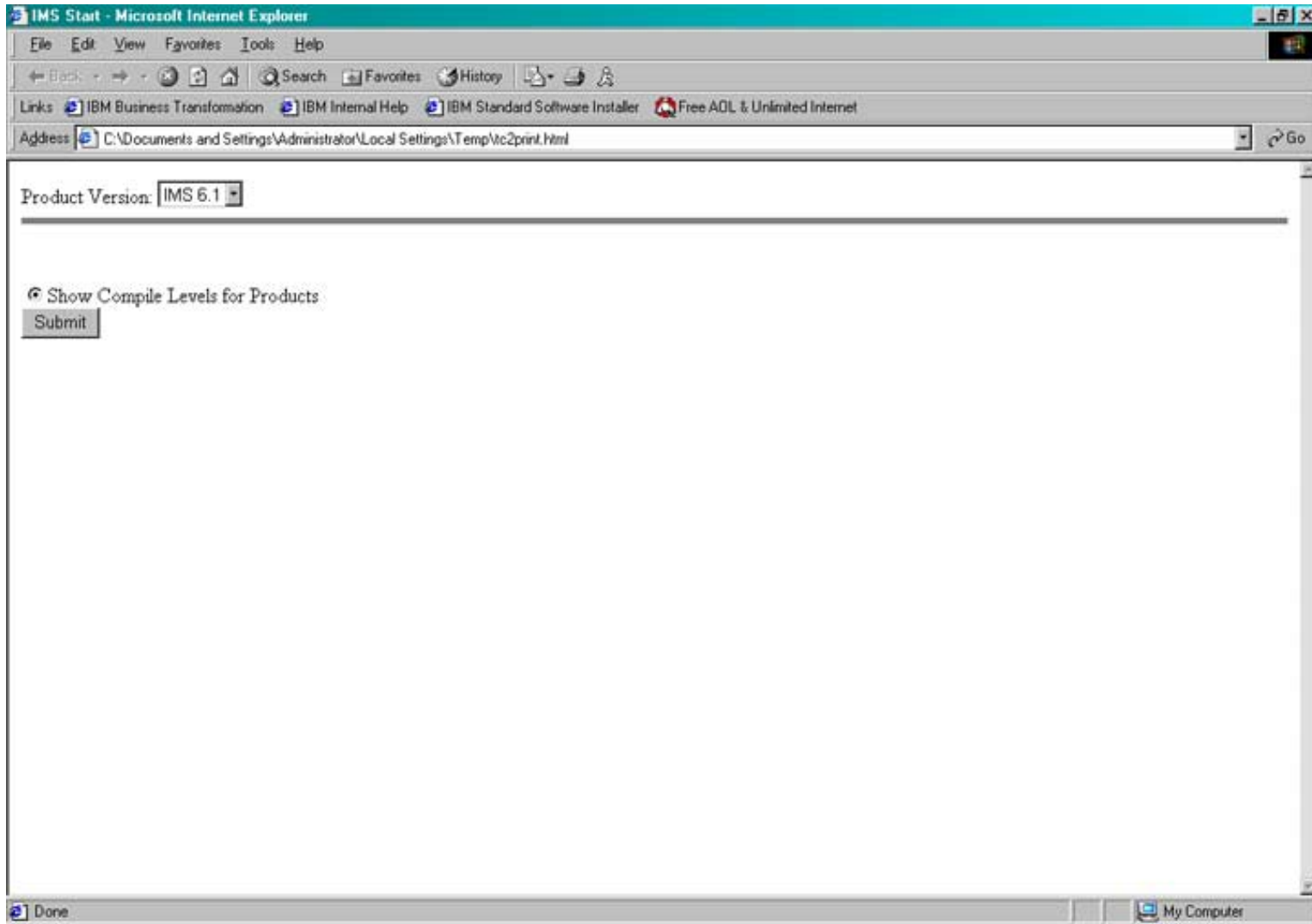
ATC Build/Execution Environment



Demo 1 of 7



Demo 2 of 7



Demo 3 of 7

Build New Query - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites History

Links IBM Business Transformation IBM Internal Help IBM Standard Software Installer Free AOL & Unlimited Internet

Address C:\Documents and Settings\Administrator\Local Settings\Temp\c3print.html Go

Product	Version
IMS	6.1

Product Version (Compile Level) - Description: IMS 6.1 (2000/04/17) -- IMS DB/TM RSR

Show All Module Groups
 Show All Testcase Groups
 Show All Apar Groups
Submit

Show All Testcases for All Modules
 Show All Modules for All Testcases
 Show All Apars for All Modules and Testcases
 Show All Modules for All Apars
 Build Worklist for An Apar
 Build Worklist for A Module
Submit

Done My Computer

Demo 4 of 7

Microsoft Internet Explorer window titled "Show Compile Levels". The address bar shows "C:\Documents and Settings\Administrator\Local Settings\Temp\vc4print.html".

Product	Version	Compile Level	Description
IMS	6.1	2000/04/17	IMS DB/TM RSR

Testcases: RSRRO8 --- /ERE NEW ACTIVE W/SECURITY

Show All Modules for A Testcase

Submit

Show Coverage For A Testcase

With Minimum Coverage: >= 0% >= 25% >= 50% >= 75%

Submit

Demo 5 of 7

The screenshot shows a Microsoft Internet Explorer browser window titled "Show All Testcases For All Modules - Microsoft Internet Explorer". The address bar displays "C:\Documents and Settings\Administrator\Local Settings\Temp\vc5sprint.html". The main content area contains a table with the following data:

Product	Version	Compile Level	Description	Testcase
IMS	6.1	2000/04/17	IMS DB/TM RSR	RSRR08

Below the table, there are three sections for filtering testcases:

- Module:** A dropdown menu showing "DFSDT300".
- Show Procedures for A Module:** A radio button option with a "Submit" button below it.
- Show Coverage for A Module and A Testcase:** A radio button option. Below it, "With Minimum Coverage:" is followed by radio buttons for ">= 0%", ">= 25%", ">= 50%", and ">= 75%". A "Submit" button is below this section.
- Show Missing Sequences For A Module and A Testcase:** A radio button option. Below it, "With Minimum Length:" is followed by a dropdown menu showing "5". A "Submit" button is below this section.

The status bar at the bottom shows "Done" and "My Computer".

Demo 6 of 7

Microsoft Internet Explorer window: Show All Modules For A Testcase - Microsoft Internet Explorer

Address: C:\Documents and Settings\Administrator\Local Settings\Temp\vcEprint.html

Product	Version	Compile Level	Description	Module	Testcase
IMS	6.1	2000/04/17	IMS DB/TM RSR	DFSDT300	RSRR08

Compile Unit	Procedure	#(Mod Stmts)	#(Mod Stmts Exec)	%(Mod Coverage)
DFSDT300	CHECK_OPEN_RC	18	0	0
DFSDT300	QUEUE_AWE	18	0	0
DFSDT300	DBRC_END_OFR	40	0	0
DFSDT300	DBRC_END_TRACK	52	0	0
DFSDT300	USID_OK	56	0	0
DFSDT300	DFSDT300	136	68	50.0
DFSDT300	DBRC_END_STREAM	38	23	60.5
DFSDT300	FREE_AWE	31	27	87.1
DFSDT300	DO_TRACE	14	14	100
DFSDT300	GETREQUEST	26	26	100

Build A New Query

Submit

Demo 7 of 7

The screenshot shows a Microsoft Internet Explorer window titled "Show Coverage for a Procedure in a Module - Microsoft Internet Explorer". The address bar shows the path "C:\Documents and Settings\Administrator\Local Settings\Temp\vc7print.html".

Product	Version	Compile Level	Description	Testcase	Module	Procedure
IMS	6.1	2000/04/17	IMS DB/TM RSR	RSRR08	DFSDDT300	DBRC_END_STREAM

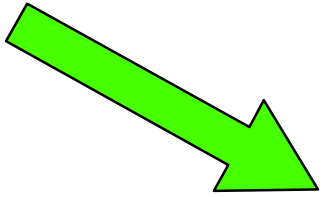

```
14249--13324      1      DBRC_END_STREAM:                                05980000 13324--
14250--13325      1      PROCEDURE OPTIONS (ENVIRONMENT (PRIMARY)); /*      */ 05990000--
14251--13326      1550V 2      IF AWLGFUNC = AWDTFSCI THEN /* /* 06000000 5162,7257--M
14252--13327      1551 2 1 +      DO; /* DSPSTCMP BRLSP (DFSBRSLSP) ECB (PS 06020000--
14253--13328      2 2 +      TECB) PSTART (AWDTSC_PLGTM) TRACK--
14254--13329      2 2 +      ER (DLI) /*--
14255--13330      1552 2 2 +      RESPECIFY--
14256--13331      2 2 +      (r1,                                268--
14257--13332      2 2 +      r15) rstd;                            296--
14258--13333      1553: 2 2 +      r1 = addr (DFSBRSLSP);                268, BI, 10289
14259--13334      1554: 2 2 +      r1 -> brlpecbp = addr (PSTECB);        268, 10291, BI
14260--13335      1555: 2 2 +      addr (r1->brlpbrlb) -> brlbf1 = brlbf1td;  BI, 268, 10298
14261--13336      1556: 2 2 +      addr (r1->brlpbrlb) -> brlbf2 = brlbf2sc;  BI, 268, 10298
14262--13337      1557: 2 2 +      addr (r1->brlpbrlb) -> brlbespt = AWDTSC_PLGTM;  BI, 268, 10298
```

Build A New Query

Submit

Agenda

- What is Code Coverage?
 - Goals/Questions addressed by code coverage
 - What is not code coverage?
- Types of Code Coverage Reports
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- **Code Coverage in Projects in IMS**
- Cross Reference Database
- Apar Regression Testing using Code Coverage



Code Coverage Projects

- **IMS V6.1 Remote Site Recovery (RSR)**
 - Provides remote disaster recovery for IMS databases
 - 380 changed modules (102 KLOC) - 90% is PL/X.
 - ▶ Result: PE prevented from reaching customer.

- **IMS V7.1 High Available Database (HALDB)**
 - Provides Partitioned Database support for Full Function
 - 178 new and changed modules (178 KLOC) - 90% is Assembler.
 - ▶ Result: Added 42 scenarios in 7 testcases

- **IMS V7.1 Online Recovery Service (ORS)**
 - Provides faster database recovery in datasharing environments
 - 146 new and changed modules (57 KLOC) - 90% is PL/X.
 - ▶ Result: Added 31 scenarios in 8 testcases (Sev 1 abend found)

- **IMS Fastpath Toolset (ODE)**
 - New product to provide Fastpath Database tool functions
 - 51 new modules (35 KLOC) - 100% is High Level Assembler.
 - ▶ Result: Improved overall coverage of product.

Code Coverage: Current Projects

■ IMS V7.1 Apar Regression Test

- 600 testcases
- 4500 executable modules (1.6 MLOC) - Mixture of HLASM and PL/X.
- Provides cross reference database for Regression Testing
 - ▶ Select testcases to test group of apar modules.
 - ▶ Verify apars are tested with testcases.

Demo 1 of 4

Microsoft Internet Explorer window titled "Show All Testcases For All Modules". The address bar shows "C:\Documents and Settings\Administrator\Local Settings\Temp\ms1print.html".

Product	Version	Compile Level	Description	Testcase
IMS	6.1	2000/04/17	IMS DB/TM RSR	RSRR08

Module:

Show Procedures for A Module

Show Coverage for A Module and A Testcase

With Minimum Coverage: >= 0% >= 25% >= 50% >= 75%

Show Missing Sequences For A Module and A Testcase

With Minimum Length:

Demo 2 of 4

Microsoft Internet Explorer window: Show All Modules For A Testcase

Address: C:\Documents and Settings\Administrator\Local Settings\Temp\vms2print.html

Product	Version	Compile Level	Description	Module	Testcase	Min(Seq Len)
IMS	6.1	2000/04/17	IMS DB/TM RSR	DFSDT300	RSRR08	5

Compile Unit	# of Sequences	Min(Seq Len)	Avg(Seq Len)	Max(Seq Len)
DFSDT300	6	15	43	108

Build A New Query

Done | My Computer

Demo 3 of 4

Microsoft Internet Explorer window titled "Show All Missing Sequences". The address bar shows the local file path: C:\Documents and Settings\Administrator\Local Settings\Temp\ms3print.html.

Product	Version	Compile Level	Description	Module	Testcase	Min(Seq Len)
IMS	6.1	2000/04/17	IMS DB/TM RSR	DFSDT300	RSRR08	5

Sequence Line Number	Sequence Length
12893	42
13001	20
13369	36
13838	108
14305	15
14404	40

Build A New Query

Done | My Computer

Demo 4 of 4

Microsoft Internet Explorer window: Show Listing of A Missing Sequence

Address: C:\Documents and Settings\Administrator\Local Settings\Temp\ms4print.html

Product	Version	Compile Level	Description	Testcase	Module	Min(Seq Len)	Start(Seq Line #)	Seq Len	Module Seqs
IMS	6.1	2000/04/17	IMS DB/TM RSR	RSRR08	DFSDT300	5	14305	15	6

```

14249--13324      1      DBRC_END_STREAM:                                05980000 13324
14250--13325      1      PROCEDURE OPTIONS (ENVIRONMENT (PRIMARY)); /*      */ 05990000
14251--13326      1550V  2      IF AWLGFUNC = AWDTFSCI THEN /*      */ 06000000 5162,7257
14252--13327      1551  2      1 +      DO; /* DSPSTCMP BRLSP (DFSBRLLSP) ECB (PS 06020000
14253--13328      2      2 +      TECB) PSTART (AWDTSC_PLGTH) TRACK
14305--13377      1584~  2      2      IF AWDTSC_PLGTH(1) = 00 X THEN /* PN92746      */ 06080040 7446
14306--13378      1585  2      3      DO; /* PN92746      */ 06080070
14307--13379      2      4
14308--13380      1586  2      4 + /*
14309--13381      2      4 +      DFSCVTN FUNC (TOLOCAL) FROM (AWDTSC_PLGTH) TO (LOCAL_TIME) PARM (PARM_AREA
14310--13382      2      4 +      ) SCDADDR (YES)
14311--13383      2      4 +
14312--13384      2      4 +
14313--13385      2      4 +      DO; /* ?DFSCVTHP FUNC (TOLOCAL) FROM (AW
14314--13386      2      5 +      DTSC_PLGTH) TO (LOCAL_TIME) PARM (

```

Build A New Query

Submit

Categories of Code Not Covered

■ Dead Code

→ Includes / Copybooks:

- ✓ Procedural copybook contains multiple routines, some of which are not used in current program

→ Obsolete logic

- ✓ Driven by obsolete values for parameters

■ Input Parsing

→ Input/Cntlcard Syntax Checking:

- ✓ Situations which are impossible
- ✓ Situations which should not occur, but are testable
- ✓ Situations which may occur
- ✓ Logic to set defaults for omitted parameters

■ Debug Logic

→ Conditional Trace Logic

- ✓ Not executed because pgm is not in trace mode

→ Residual Debug Code from debugging logic problems

Categories of Code Not Covered

■ Error Situations

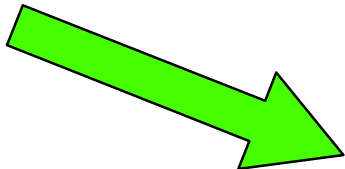
- Message Generation, Abend Routines, DL/I Status Code Checking
 - ✓ Situations which are impossible
 - ✓ Situations which should not occur, but are testable
 - ✓ Situations which may occur
- System Service Failures:
 - ✓ Unsuccessful Getmain Logic
 - ✓ Open errors
 - ✓ Read failures

■ Missed Functional Areas

- Large sequences of missing coverage

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- **Cross Reference Database**
- Apar Regression Testing using Code Coverage



Cross Reference Database

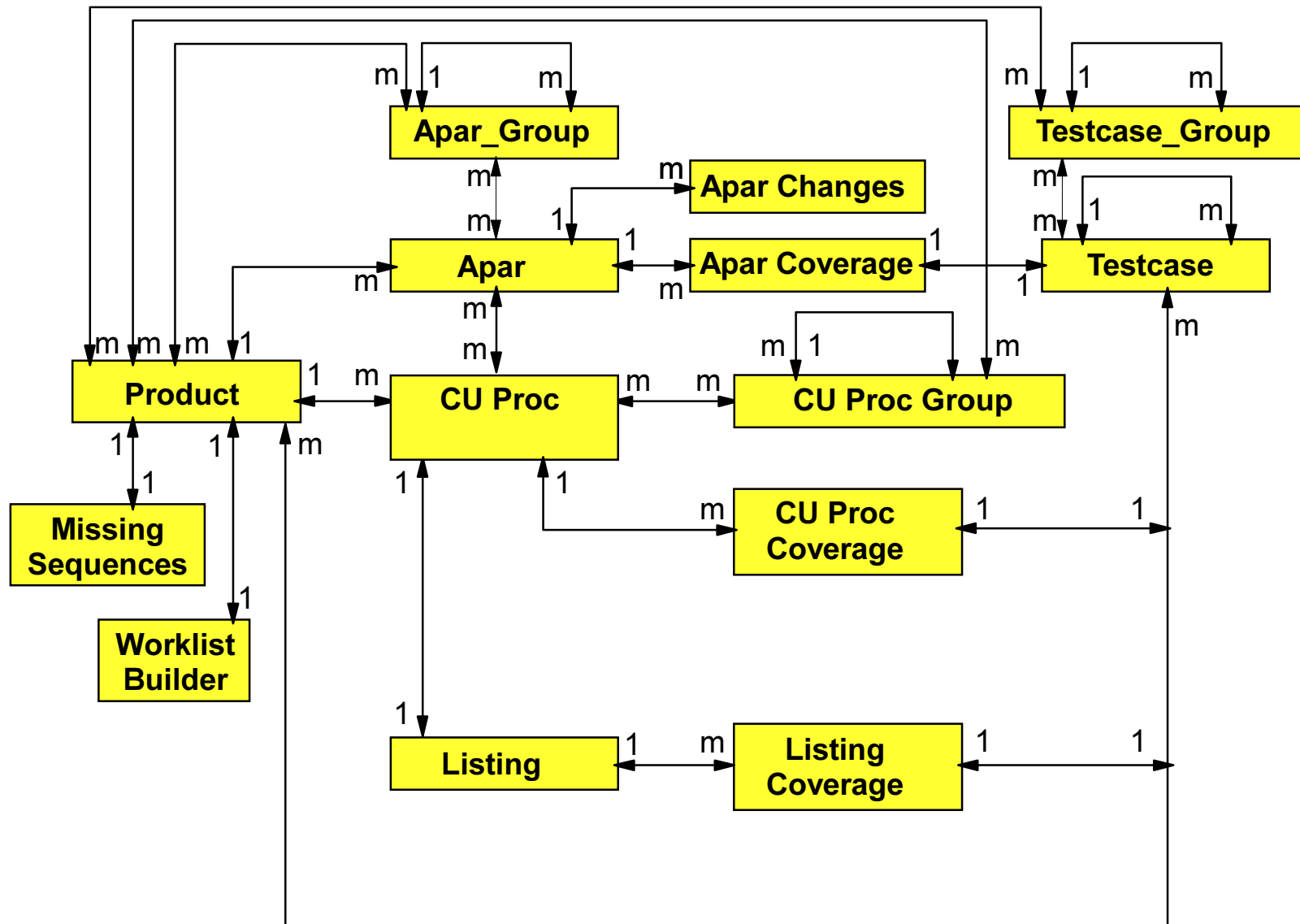
■ Cross Reference Database

- Production Platform
 - ▶ DB2 UDB database OS/390
 - ▶ Net.Data application running on OS/390 Web Server

- Database Population
 - ▶ Testcases automatically create reports after execution
 - ▶ Reports are parsed and database populated
 - ▶ Analysis done on missing sequences during parsing

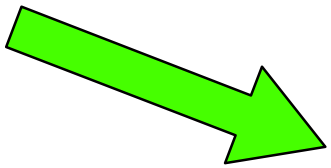
- Query Capability
 - ▶ Net.Data application queries database from Web Browser

Cross Reference Database



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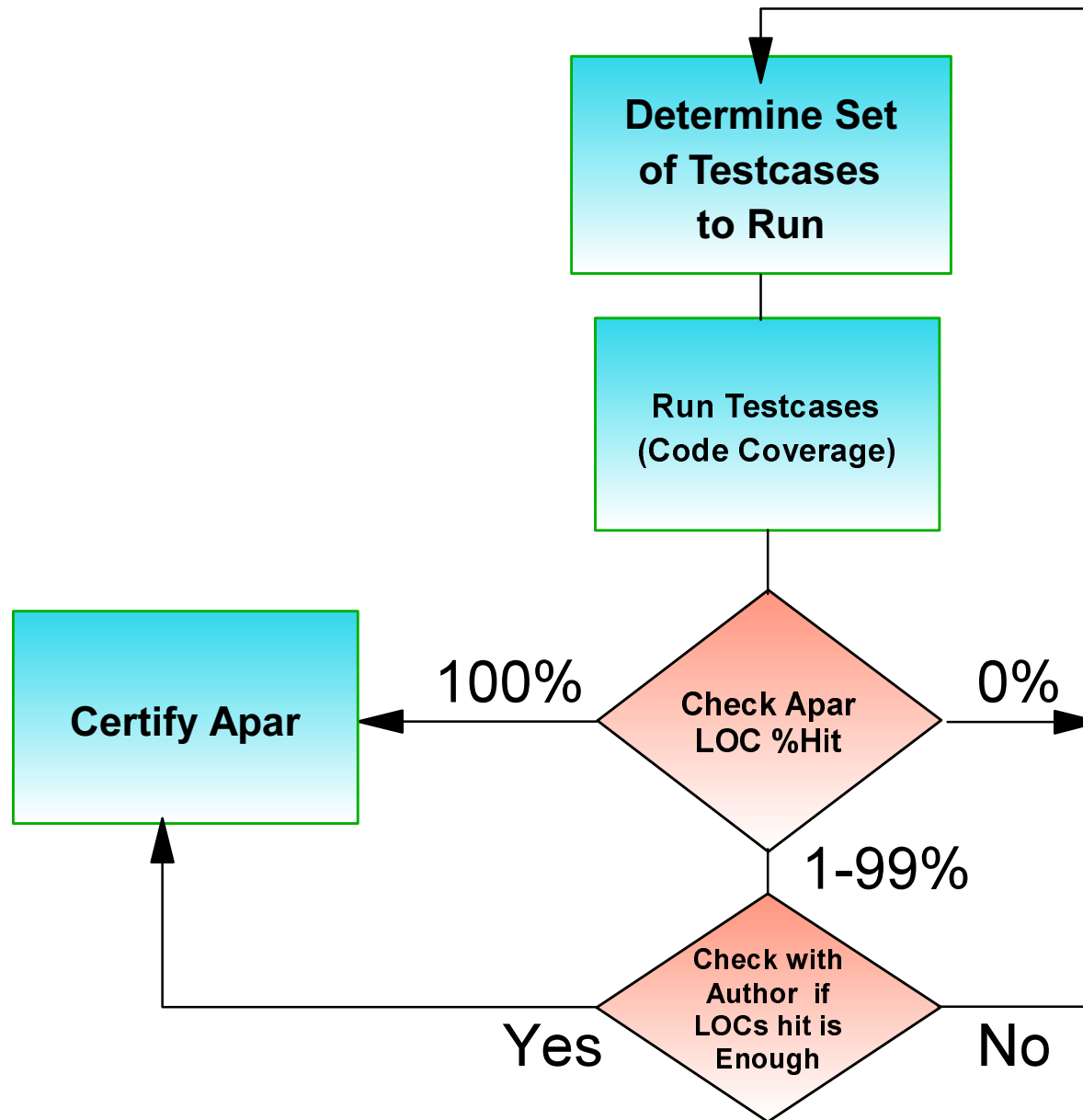


Apar Regression Testing

■ Apar Regression Testing

- Enable code coverage on changed Apar modules
 - ▶ Ensure each Apar LOC is hit during test
 - ▶ Redefine "Successful Apar Regression Test"
 - ✓ Testcase did not fail
 - ✓ Apar LOCs were hit
- Use Cross Reference Database
 - ▶ Identify only the testcases that hit the changed Apar modules
 - ✓ Run all Regression Apar Testcases (600 TCs)
 - ✓ Monitor all IMS Modules (about 4500 modules)
 - ✓ Populate database after each testcase run
- Reduce time to test each Apar
 - ▶ Fewer apars in each run (less analysis time)
 - ▶ Fewer testcases in each run (less run time)

Apar Code Coverage Process



Apar Regression Test Benefits

- Reduce PE Rate with higher quality tests
- Code coverage results are documented and saved
 - Results may be used in PE analysis
- Apars that Fail Apar Regression Test
 - Submitted sooner to subsequent Apar Regression Test
- Identify code coverage holes in regression test bucket

Demo 1 of 6

Build New Query - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites History

Links IBM Business Transformation IBM Internal Help IBM Standard Software Installer Free AOL & Unlimited Internet

Address C:\Documents and Settings\Administrator\Local Settings\Temp\ap1.print.html Go

Product	Version
IMS	6.1

Product Version (Complete Level) - Description: IMS 6.1 (2000/04/17) -- IMS DB/TM RSR

Show All Module Groups
 Show All Testcase Groups
 Show All Apar Groups
Submit

Show All Testcases for All Modules
 Show All Modules for All Testcases
 Show All Apars for All Modules and Testcases
 Show All Modules for All Apars
 Build Worklist for An Apar
 Build Worklist for A Module
Submit

Done My Computer

Demo 2 of 6

Microsoft Internet Explorer window titled "Show Compile Levels". The address bar shows "C:\Documents and Settings\Administrator\Local Settings\Temp\ap2print.html".

Product	Version	Compile Level	Description
IMS	6.1	2000/04/17	IMS DB/TM RSR

Apars:

Show All Testcases for an Apar
 Show All Modules for an Apar

Show Coverage For an Apar

Ordered By:
 = Testcase Ascending Descending
 = Compile Unit Ascending Descending

With Minimum Coverage: >= 0% >= 25% >= 50% >= 75%

Demo 3 of 6

Product Version Compile Level Description Apar

IMS	6.1	2000/04/17	IMS DB/TM RSR	PN92746
-----	-----	------------	---------------	---------

Modules: DFSDT300

Show Testcases for Apar and Module

Submit

Show Coverage For Apar and Module

Ordered By:

= Testcase Ascending Descending

With Minimum Coverage: >= 0% >= 25% >= 50% >= 75%

Submit

Demo 4 of 6

Microsoft Internet Explorer window titled "Show All Modules For An Apar". The address bar shows "C:\Documents and Settings\Administrator\Local Settings\Temp\ap4print.html".

Product	Version	Compile Level	Description	Apar	Module
IMS	6.1	2000/04/17	IMS DB/TM RSR	PN92746	DFSDT300

Testcases:

Show Coverage For Apar, Testcase and Module

With Minimum Coverage: >= 0% >= 25% >= 50% >= 75%

Demo 5 of 6

The screenshot shows a Microsoft Internet Explorer window titled "Show All Testcases For An Apar and Module - Microsoft Internet Explorer". The address bar displays "C:\Documents and Settings\Administrator\Local Settings\Temp\ap5print.html". The main content area contains two tables. The first table lists test cases, and the second table shows coverage statistics for the compile unit DFSDT300. Below the tables is a link to "Build A New Query" and a "Submit" button.

Product	Version	Compile Level	Description	Testcase	Apar	Compile Unit
IMS	6.1	2000/04/17	IMS DB/TM RSR	RSRR08	PN92746	DFSDT300

Compile Unit	#(Lines in Apar)	#(Stmts With Coverage)	#(Apar Stmts Exec)	%(Apar Coverage)
DFSDT300	14	10	8	25.0

[Build A New Query](#)

Demo 6 of 6

Microsoft Internet Explorer window: Show Listing of All Apars

Address: C:\Documents and Settings\Administrator\Local Settings\Temp\ap6print.html

Product	Version	Compile Level	Description	Testcase	Module	Apar	#(Lines in Apar)	#(Stmts With Coverage)	#(Apar Stmts Exec)	%(Apar Coverage)
IMS	6.1	2000/04/17	IMS DB/TM RSR	RSRR08	DFSDT300	PN92746	14	10	8	25.0

```

14110--13194      2  +
                                     RT(AWDINT_PLGTH) DEALTIME (AWDINT
14111--1
14112--PL/X-370 V01 REL 03.10 DFSDT300 -- DB TRACKING SAS QUEUE SERVER
                                     Page 259
14113--Line Stmt Lev Nest -L-----1-----2-----3-Source-4-----5-----6-----7-R-----8 Line References
14114--13195      2  -
                                     T_E_TIME) USID (AWDINT_USID) /*
14115--13196      1510 2          RCODE = R15; /*
14116--13197      1511~ 2          IF RCODE ^= ZERO THEN /*
14117--13198      1512 2  1          DO; /* FAILURE /*
14118--13199      1513~ 2  2          IF AWDINT_PLGTH(1) ^= DO X THEN /* PN92746 /*
14119--13200      1514 2  3          DO; /* PN92746 /*
14120--13201      2  4
14121--13202      1515 2  4 + /*
14122--13203      2  4 + DFSCVTH FUNC (TOLOCAL) FROM (AWDINT_PLGTH) TO (LOCAL_TIME) PARM (PARM_AREA
14123--13204      2  4 + ) SCDADDR (YES)
14124--13205      2  4 +
14125--13206      2  4 +
    
```

Build A New Query

Submit

Done My Computer

Conclusion

- Code coverage adds a new quality testing dimension
- Useful in IMS for
 - Lineitems
 - Apar Regression Testing
 - New Products
- Useful for IMS Application Testing
- Cross Reference Database
 - Allows intelligent reuse of testing data