Principles, Challenges, Techniques, and Tools for the Testing of Immunization Forecasting Software: Introductory Comments

AIRA National Meeting

Seattle, WA

April 5, 2016

Noam H. Arzt, PhD, FHIMSS
President, HLN Consulting, LLC
Moderator

Premise: Common Challenge

- All IIS are faced with is the need to repeatedly test their immunization decision support solution whenever it is updated to support new vaccines or rule changes from the Advisory Committee on Immunization Practices (ACIP)
- IIS also confront this testing challenge when they attempt to compare their existing immunization decision support software to other solutions.

Three Part Session

1. More theoretical: Basic concepts in immunization forecast algorithm testing
2. Generation of test data by Oregon ALERT using WIR
3. Fully-implemented web-based testing harness using ICE/CAT

Presenter Bios

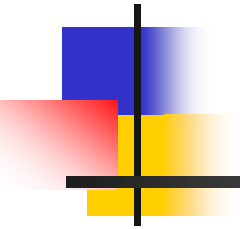
- **Nathan Bunker** is a senior technical project manager for the American Immunization Registry Association (AIRA) with a focus on immunization software and data exchange. In the past ten years he has consulted or collaborated with many state, local, and federal immunization registry projects; written software applications; presented at national immunization conferences; and participated in CDC technical advisory groups. Nathan is now fully engaged on IIS Interoperability Project and is working to help all IIS align with community-directed standards.

Presenter Bios *(continued)*

- **Amanda Timmons** has worked in the immunization field for over 20 years. She's held numerous positions in the Oregon Immunization Program, beginning as a VFC Health Educator and moving on to perinatal hepatitis B prevention, school law coordinator and working on the team that replaced their homegrown IIS, ALERT, with a version of the Wisconsin Immunization Registry (WIR). In the IIS world, Amanda maintains the immunization forecaster for the ALERT IIS and served on the subject matter expert panel for the Clinical Decision Support for immunization (CDSi) project.

Presenter Bios *(continued)*

- **Mike Suralik** has been a Project Manager with HLN Consulting for more than 10 years. Mike has managed needs assessment projects and software development projects for immunization programs around the country as well as for health information exchanges and the CDC. Since 2005, Mike has been managing HLN's ongoing support of the New York City Citywide Immunization Registry. Mike has also been a leader in the collaboration that is creating the Immunization Calculation Engine (ICE), an open-source clinical decision support system for immunizations.



Now On With The Show!

Basic Concepts of Immunization Forecast Software Testing

AIRA National Meeting
Seattle WA – April 5, 2016 – Nathan Bunker

Introducing CDSi

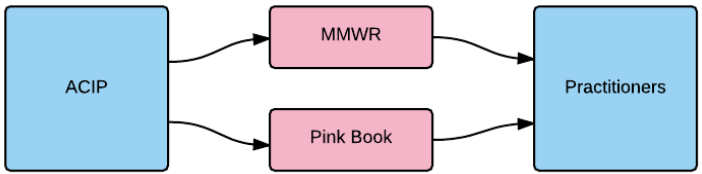
How this CDC project is changing the future of forecasting

Introducing CDSi

- Clinical Decision Support for Immunization (CDSi)
  - Project supported by the Immunization Information Services Support Branch
- Promotes and supports the use of immunization forecasters
- Working for: Clarity, Consistency, and Computability
- Products include:
  - Logical specification
  - Supporting data
  - Test cases and user guide
  - Web based training and user support

Evolution of CDSi

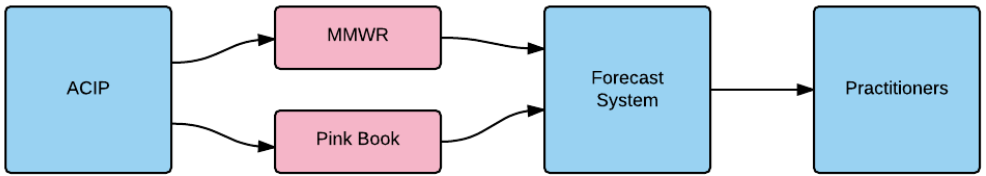
- In the beginning….



- ACIP made recommendations for humans to follow
- MMWR and Pink Book explained and published these
- Practitioners read the recommendations and decided how they applied for a specific patient
- Result: Recommendations are optimized for human computation
  - Vaccines recommended on easy to follow calendar events (2, 4, 6 months)

Evolution of CDSi

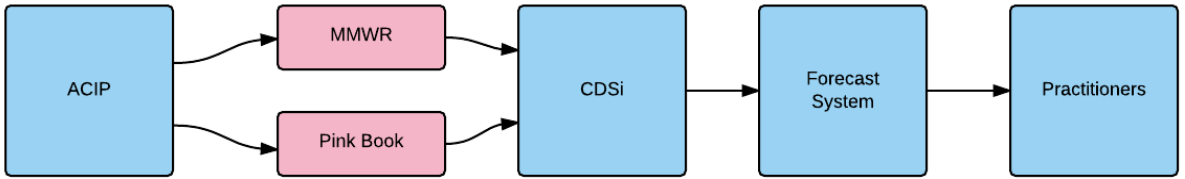
- Now we try to automate…



- Solved a growing problem:
  - Over time ACIP recommendations increase in complexity
  - Inconsistent practice and mistakes can impact patient and public health
  - Humans can only remember so many rules
  - Computers can be very consistent and remember many rules
- Problem encountered:
  - Recommendations written for humans not computers

Evolution of CDSi

- Now better national support…



- Solved a common problem:
  - Translated human statements into computable artifacts
  - Identified areas that need additional guidance and clarification
  - Created a standard set of test cases

Introducing CDSi

- If you use or support a forecasting system, look at using CDSi:
  - Resources to improve forecast software
  - Test cases as a starting point for testing
  - Test methodology to create additional test cases for local use
- More information can be found here:
  - http://www.cdc.gov/vaccines/programs/iis/cdsi.html
  - Or just google “CDSi”

Original Vision

How Texas Children's Hospital saw the future forecasting

Vision from Texas Children's Hospital (TCH)

- **Standardization**
  - Forecaster results are consistent across different systems
- **Accurate**
  - Based on most recent ACIP/CDC recommendations
- **Universally and easily accessible**
  - Standard part of continuity of care

TCH Team Acknowledgements

- Dr Julie Boom
- Brady Kerr
- Rachel Cunningham
- Leila Sahni
- Gordon Chamberlin
- Laura King

Vision from Texas Children's Hospital (TCH)

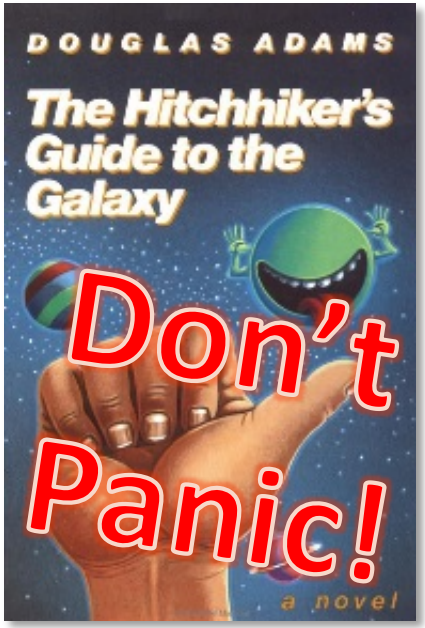
- Nationally centralized system for testing forecast systems
  - Database of test cases with expected results
  - Opinions and notes from immunization experts
  - Actual results from multiple forecast systems
- TCH created the TCH Forecast Tester
  - Test cases: 7,530
  - Forecasters integrated: 5
  - Users registered: 58

Testing Methods

Learn three different ways to test a forecasting system

Three Methods of Testing

- Exact Testing
  - Create test cases with expected responses
  - Test cases are adapted to each forecaster
  - Verify forecaster meets expectations exactly



- General Testing
  - Select an external test set (e.g. CDSi test cases)
  - Be careful: expect false negatives when testing
  - A general test set can be adapted for Exact Testing by carefully reviewing all expectations

- Comparison Testing
  - Used when comparing with one or more forecasters
  - Leverages historical knowledge embodied in software
  - Useful when looking to transition to a new system

Exact Testing: Comparing Actual vs Expected

Test Case

COPY EDIT

Category	MMR
Label	MMR Test 1
Description	The minimum age for dose 1 is 12 months old. #1 on or after first birthday is valid
Vaccine Group	
Include Status	Included
Result Status	Pass
Number	438
Patient	Jillian Paulina (F)
Birth Date	07/01/2004
Assessment Date	07/12/2011

Vaccination History

EDIT

#	Vaccination	CVX	MVX	Date	Age
1	MMR	03		06/27/2005	Almost 12 Months

Exact Testing: Comparing Actual vs Expected

Actual vs Expected for MMR

PREVIEW EDIT

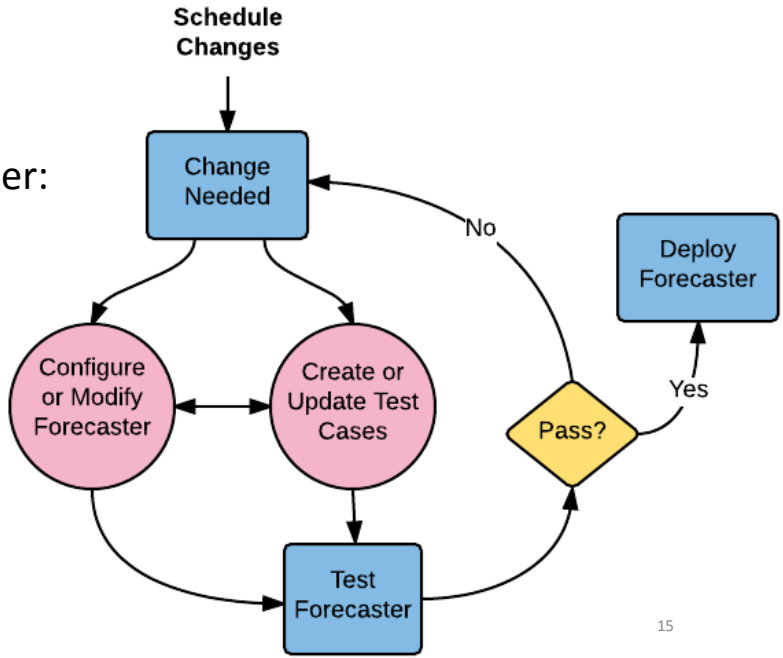
Forecast

Entity	Status	Dose	Earliest	Recommend	Past Due
Expected by Laura King at TCH	Overdue	2	07/25/2005	07/01/2008	07/01/2011
Actual from TCH Forecaster for Testing	Overdue	2	07/25/2005	07/01/2008	07/01/2011
Actual from TCH Forecast for IHS	Overdue	2	07/25/2005	07/01/2008	07/01/2011

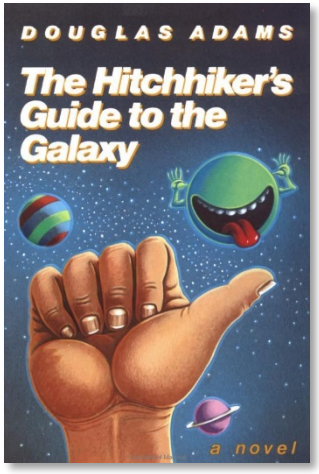
- The immunization expert sets the EXACT response that is required
- Software verifies that the matching response is returned

Exact Testing: Comparing Actual vs Expected

- Schedule changes
  - ACIP decisions
  - Forecaster improvement needed
- Change Needed
  - Prioritize changes needed
- These steps must happen together:
  - Configure or Modify Forecaster
  - Create or Update Test Cases
- Test Forecaster
  - Automated with testing tool
- Deploy Forecaster

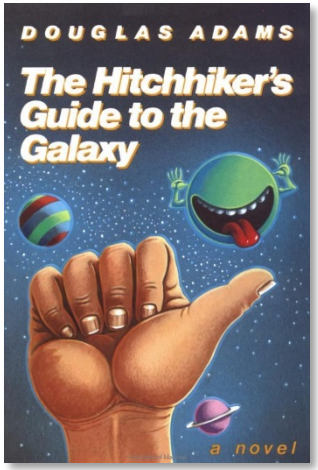


General Testing: CDSi Test Cases



- Test cases taken from other projects can be used for General Testing
- These can be further adapted to be Exact Tests
- CDSi provides:
  - 768 test cases
  - Developed by immunization community experts
- Limitations
  - Subject to revision and improvement
  - Focused on edge cases and areas of community discussion
  - Test set is for general use and are not definitive, complete or final
  - Will need to be completely reviewed, updated and expanded in order to fully test a production system

General Testing: CDSi Test Cases



- In actual practice some forecasters may return good results that do not match CDSi expectations.
- CDSi test cases define all information that could be returned but the forecaster may support less
- Past due dates can be different and still be correct
  - But past due dates are used either to ensure patients stay up-to-date or to determine if patients are up-to-date
  - ACIP provides limited guidance on when vaccines would be past due
  - Past due dates do not directly affect recommendations
  - CDSi sets past due dates in test cases to be helpful
- Corner cases can cause differences to appear
  - Earliest and valid dates may be different depending on how catch-up schedules are calculated
  - Some differences do not have clinical impact but are rather artifacts of how the result is calculated

General Testing: CDSi Test Cases Example

Schedule for IPV (Polio)

- Dose 1: **2 months**
- Dose 2: **4 months**
- Dose 3: **6-18 months**
- Dose 4: **4-6 years**

Catchup Rule

A fourth dose is not necessary if the third dose was administered at age 4 years or older and at least 6 months after the previous dose.

- Catchup example from two Forecasters:
  - DOB: **01/01/2012**
  - Dose 1: **03/01/2012**
  - Dose 2: **05/01/2012**
- Forecasters give matching recommendations:
  - Forecaster A: **Last dose of IPV due today**
  - Forecaster B: **Last dose of IPV due today**
- But the details include these notes:
  - Forecaster A: **IPV can be given on or after 05/29/2012**
  - Forecaster B: **IPV can be given on or after 01/01/2016**

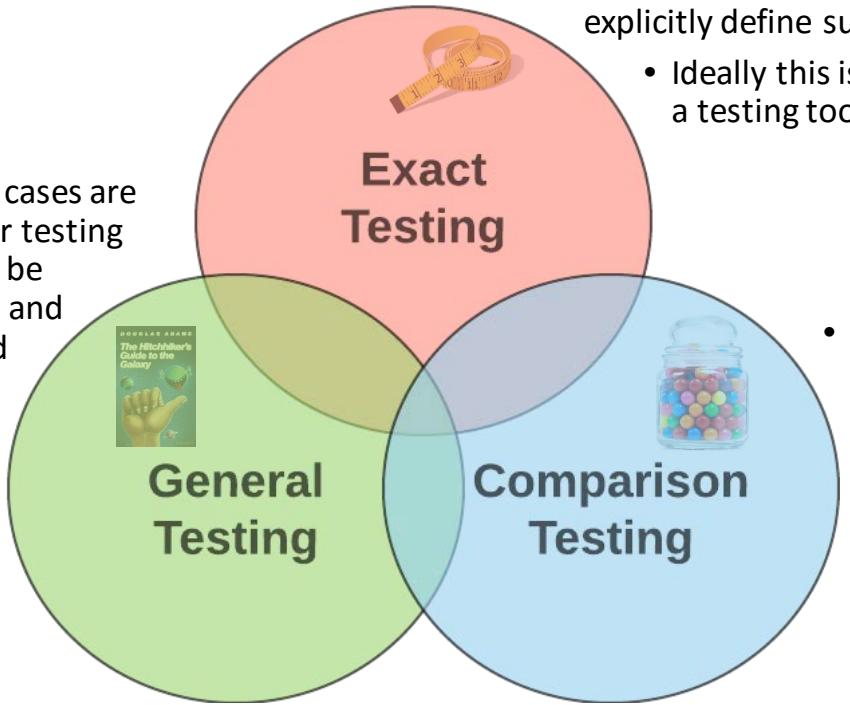
- Both answers are accurate!
- It is not enough to simply match actual dates with expected dates
- Expert guidance is needed to interpret results

Comparing Testing: Group Consensus

- Comparison testing is helpful when
  - Verifying forecaster against other forecasters
  - Evaluating a transition to a new forecaster
- TCH Forecast Tester can compare a forecaster against a set of forecasters and identify results that are:
  - Same as all others
  - Same as at least [n] others
  - Different than all others and others don't agree
  - Different than all others and others have mixed agreement

Summary

- Every forecast system must have a customized set of test cases that explicitly define success
  - Ideally this is automated with a testing tool



- CDSi test cases are critical for testing but must be reviewed and expanded for Exact Testing
- Forecasting results can be compared and imbedded system knowledge captured

Contact Information

Nathan Bunker

Senior Technical Project Manager
American Immunization Registry Association

nbunker@immregistries.org

Testing a CDSi Engine

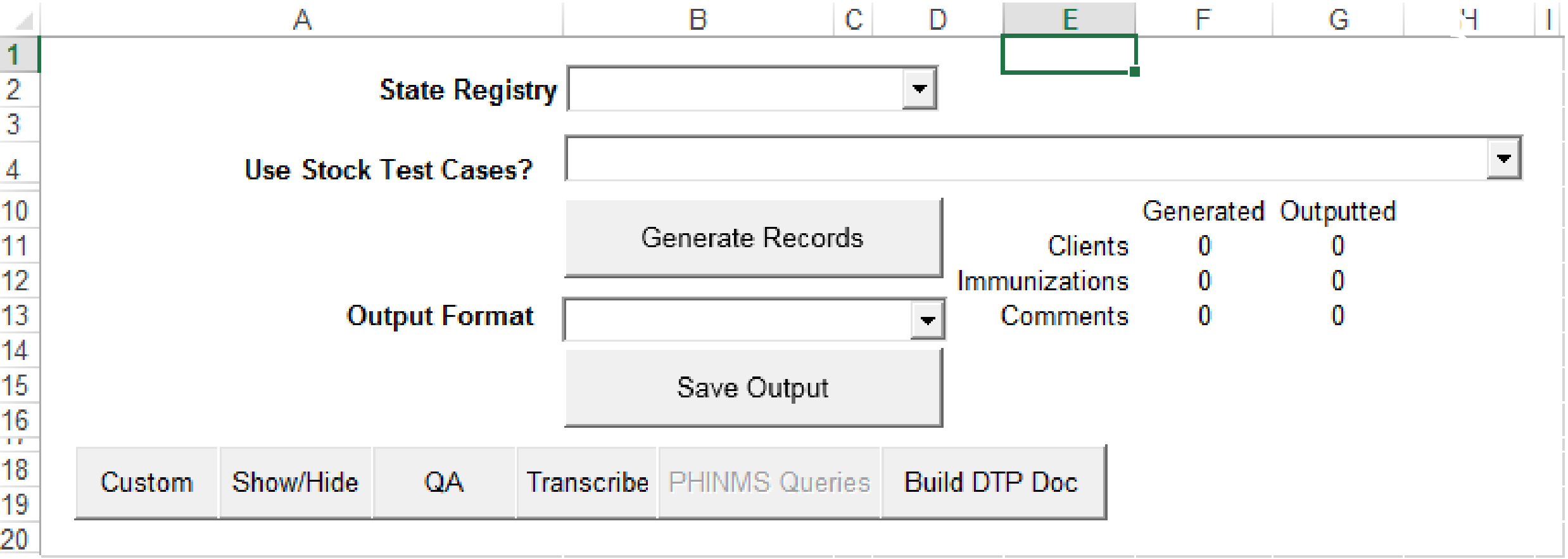
Amanda Timmons

ALERT IIS

Oregon Immunization Program

Dating Test Cases

- 2 basic options:
  - Aging test cases
    - Changing the date of birth and immunization dates to keep the patient's age constant.
  - Changing the evaluation date
    - Changing the system date to adjust the patient's age.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Use Stock Test Cases?
Generate Records
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Clients 0 0
Immunizations 0 0
Comments 0 0
Output Format
Save Output
Custom
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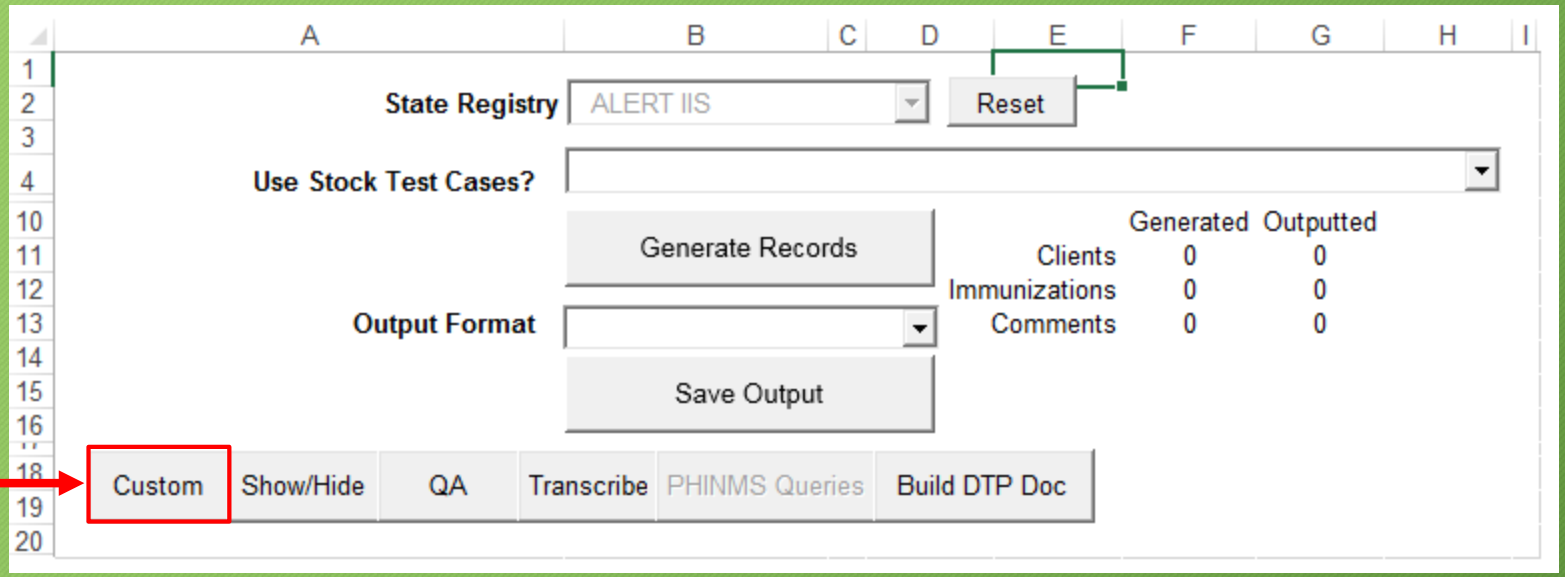
QA
Transcribe
PHINMS Queries
Build DTP Doc

Creating Custom Cases

Main Screen – Click on the Custom button



A	B
Test Case:	New Test Cases 22

Do not enter anything above this line

Client

Test Case:	New Test Cases 22															
	Test Case Number	Age in Years	Age in Months	Age in Days	Gender	Specific DOB	Mother's HBsAG Status	American Indian or Alaska Native	Asian	Native Hawaiian or Other Pacific Islander	Black or African-American	White	Other Race	Social Security	Medicaid Number
	Do not enter anything above this line														
client															

Immunization

Test Case:	New Test Cases 22												
	Test Case Number	Imm Age in Years	Imm Age in Months	Imm Age in Days	Vaccine Group	CPT Code	Trade Name	Info Source #	Specific Imm Date	CVX Code	NDC Code	Purchased With	Reaction
	Do not enter anything above this line												
imm													

Test Case:	New Test Cases 33															
	Test Case Number	Age in Years	Age in Months	Age in Days	Gender	Specific DOB	Mother's HBsAG Status	American Indian or Alaska Native	Asian	Native Hawaiian or Other Pacific Islander	Black or African-American	White	Other Race	Social Security	Medicaid Number
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CLIENT	HEPB CASE 1			0	F											
CLIENT	HEPB CASE 2			0	F		POSITIVE									
CLIENT	HEPB CASE 3		3		F											
CLIENT	HEPB CASE 4			8	F		POSITIVE									
CLIENT	HEPB CASE 5			11	F											
IMM	HEPB CASE 5			1		90731										
CLIENT	HEPB CASE 6R		1		F											
IMM	HEPB CASE 6R			7		90731										
CLIENT	HEPB CASE 7		1		F											
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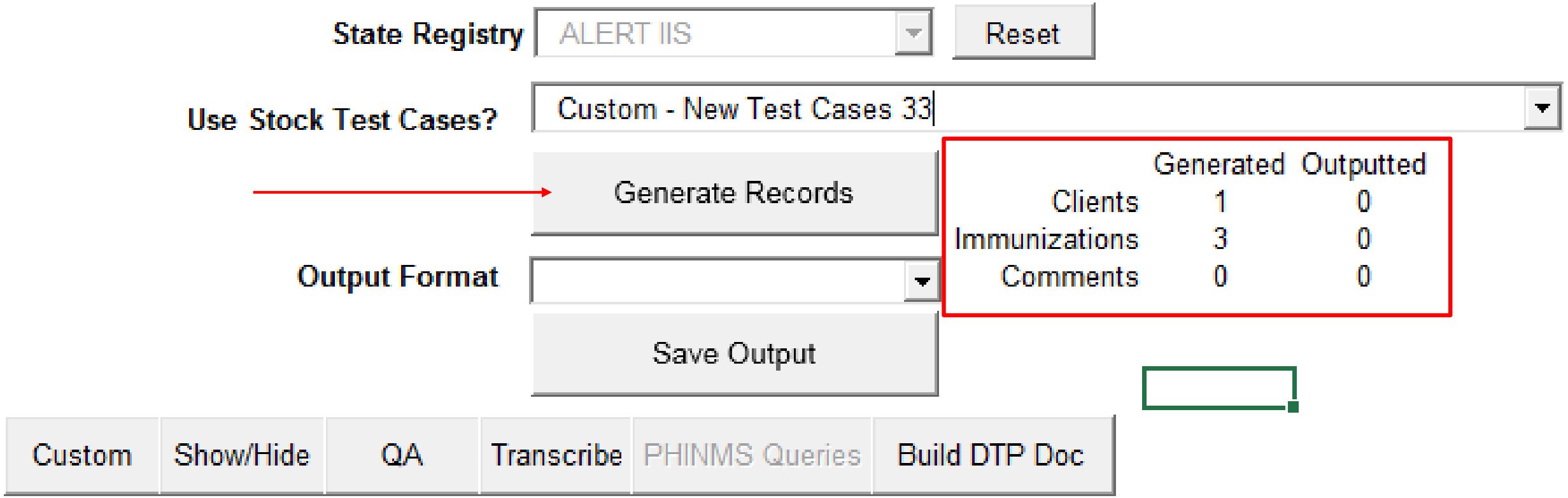
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Immunizations 3 0
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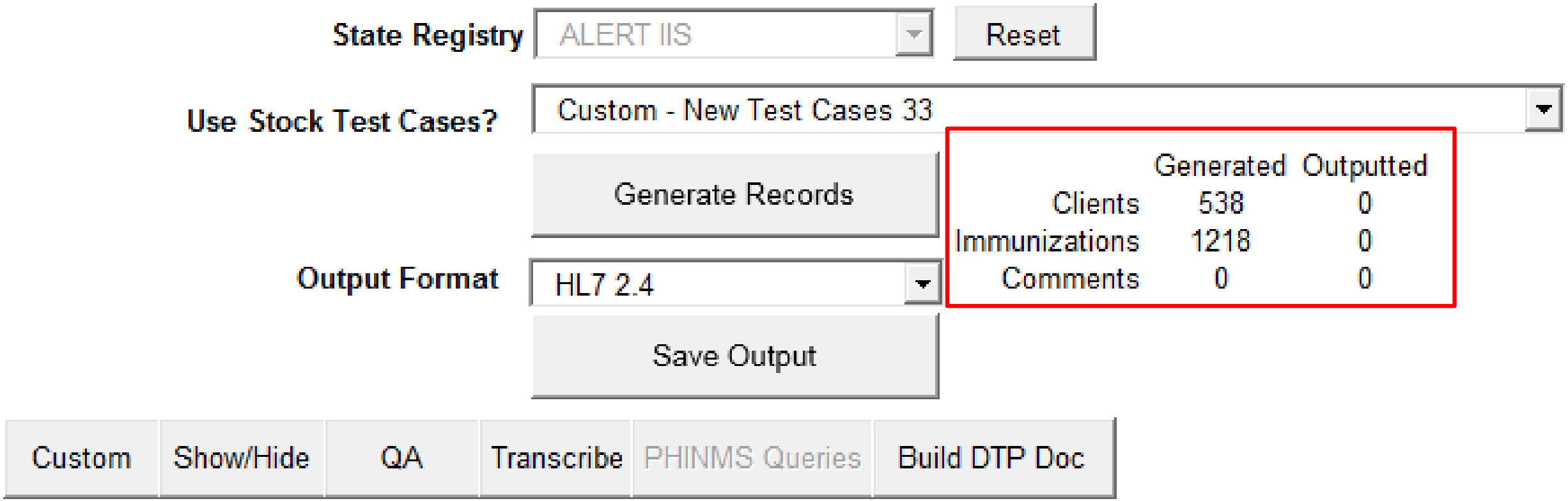
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Save Output
Custom
Show/Hide
QA
Transcribe
PHINMS Queries
Build DTP Doc

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5	HEPB CASE 4		DOREEN	BETH	BAUMM		03032016		SUSAN	NEESON	F	HEPB CASE 4	230 PICKNEY	
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10	HEPB CASE 9R		DARLENE	CAROLYN	CASH		02022016		CHRISTY	PARKER	F	HEPB CASE 9R	854 KING	
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31	T FAMILY CASE 4		BRITTANY	LINDA	MESSIER		01112016		ASHLEY	MORRIS	F	FAMILY CASE 4	325 MILWAU	
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Main | Client Records | Imm Records | Comment Records | Clients | Imms | Comments | State-Specific Formats | Lookup | Street Nar ...

Zoom Out

Record Identifier	Vaccine Group	CPT Code	Trade Name	Vaccination Date	Administration Route Code	Body Site Code	Reaction Code	Manufacturer Code	Immunization Information Source	Lot Number	Provider Name	Administered By Name	Sending Org	CVX Code
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HEPB CASE 24		90731		07112015					01					
HEPB CASE 24		90731		12112015					01					
HEPB CASE 24		90731		01112016					01					

Advantages

- Readily available tool
- Custom test cases
- Minimal maintenance

Disadvantages

- Not automated – creates a file to load into the IIS, doesn't produce results
- Must have detailed knowledge of schedule and spacing
- Time consuming

Contact

Amanda Timmons

Oregon Immunization Program

amanda.j.timmons@state.or.us

971-673-0312

CDS Administration Tool (CAT)

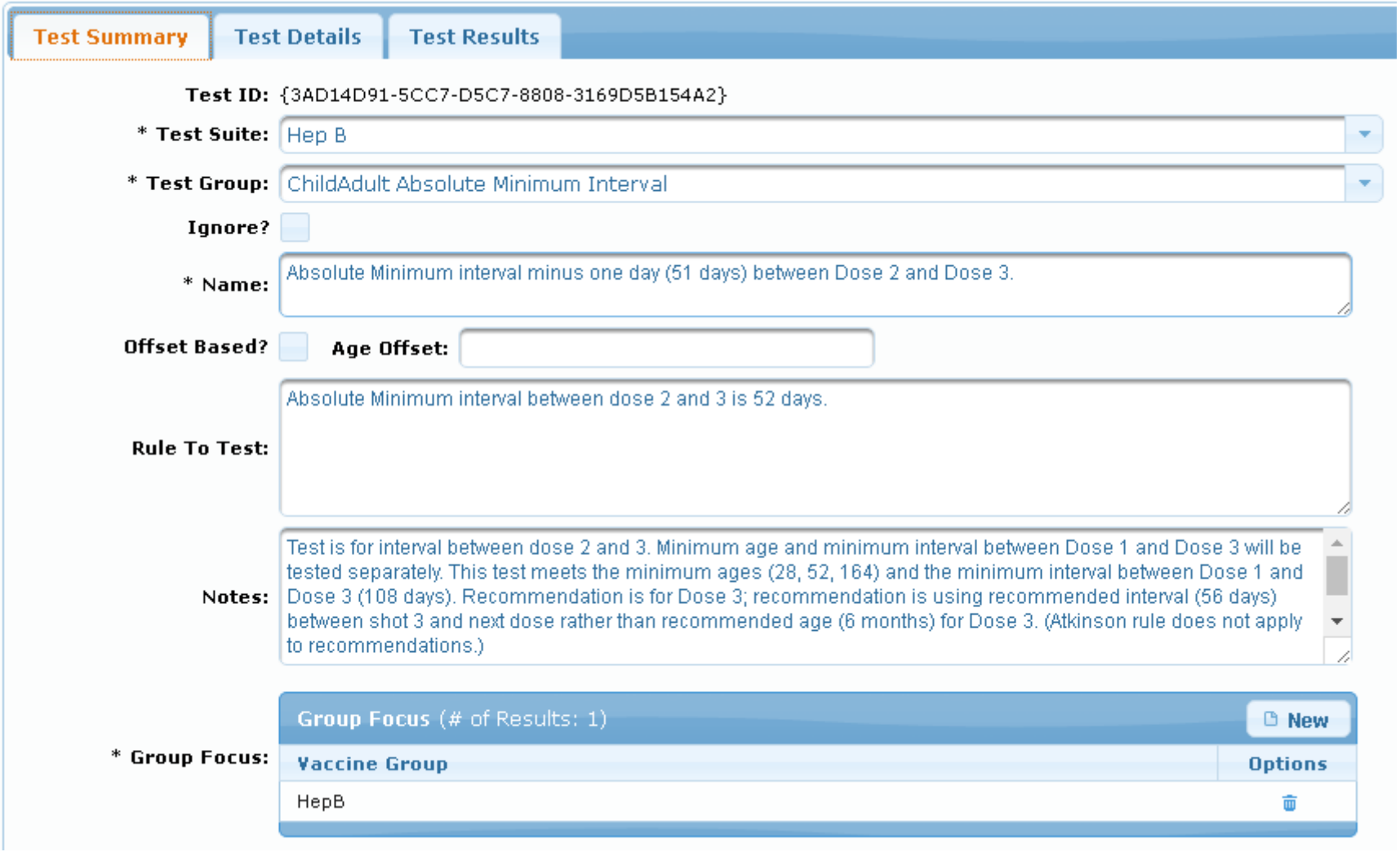
- Purpose
  - Manage the ICE immunization schedule
  - Create, edit, delete, test cases (2,600+)
  - Automated testing
- Graphical user interface
- Usable by non-technical SMEs

Attributes of a Test Case

- Inputs
  - Date of Birth
  - Gender
  - Immunization history (vaccine + administration date)
  - Proof of Immunity and Documented Disease
  - Assessment/Execution Date
- Expected Outputs:
  - Validity of immunization history + reasons
  - Immunization recommendation + reason

Sample Test Case in CAT

Descriptive Summary



Test Case Data

* **Date of Birth:** 04/01/2011 **Age @ Execution Date:** 6 months 20 days (203 days)

* **Execution Date:** 10/21/2011 **Set Execution Date @ Age:** Set

* **Gender:** Female (F)

Proof of Immunity/Documented Disease (# of Results: 0) New

Antigen	Immunity Date	Age @ Imm Date	Immunity Reason	Delete
No records found.				

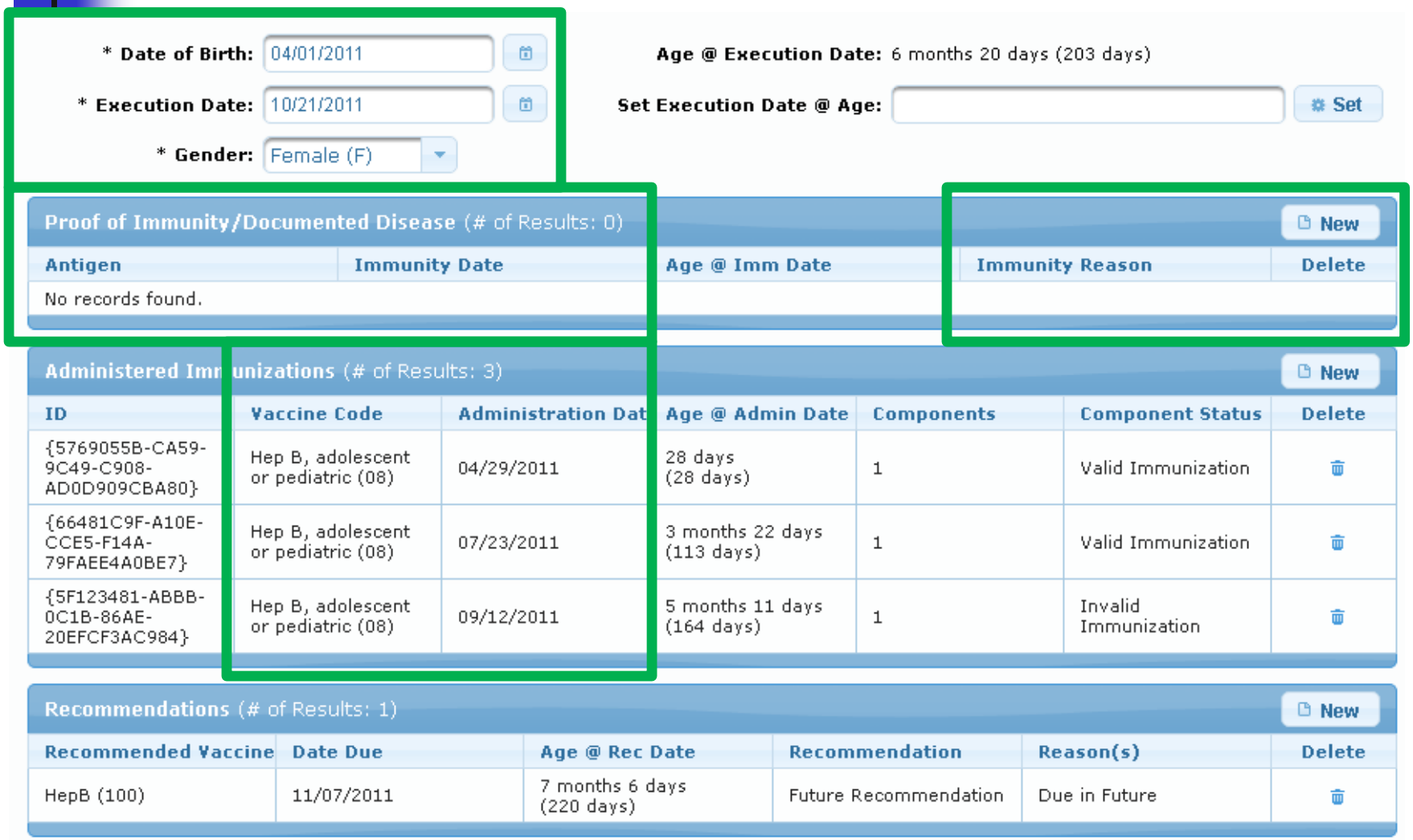
Administered Immunizations (# of Results: 3) New

ID	Vaccine Code	Administration Dat	Age @ Admin Date	Components	Component Status	Delete
{5769055B-CA59-9C49-C908-AD0D909CBA80}	Hep B, adolescent or pediatric (08)	04/29/2011	28 days (28 days)	1	Valid Immunization	
{66481C9F-A10E-CCE5-F14A-79FAEE4A0BE7}	Hep B, adolescent or pediatric (08)	07/23/2011	3 months 22 days (113 days)	1	Valid Immunization	
{5F123481-ABBB-0C1B-86AE-20EFCF3AC984}	Hep B, adolescent or pediatric (08)	09/12/2011	5 months 11 days (164 days)	1	Invalid Immunization	

Recommendations (# of Results: 1) New

Recommended Vaccine	Date Due	Age @ Rec Date	Recommendation	Reason(s)	Delete
HepB (100)	11/07/2011	7 months 6 days (220 days)	Future Recommendation	Due in Future	

Inputs



* Date of Birth: 04/01/2011
* Execution Date: 10/21/2011
* Gender: Female (F)

Age @ Execution Date: 6 months 20 days (203 days)

Set Execution Date @ Age: Set

Proof of Immunity/Documented Disease (# of Results: 0) — New

Antigen	Immunity Date	Age @ Imm Date	Immunity Reason	Delete
No records found.				

Administered Immunizations (# of Results: 3) — New

ID	Vaccine Code	Administration Dat	Age @ Admin Date	Components	Component Status	Delete
{5769055B-CA59-9C49-C908-AD0D909CBA80}	Hep B, adolescent or pediatric (08)	04/29/2011	28 days (28 days)	1	Valid Immunization	
{66481C9F-A10E-CCE5-F14A-79FAEE4A0BE7}	Hep B, adolescent or pediatric (08)	07/23/2011	3 months 22 days (113 days)	1	Valid Immunization	
{5F123481-ABBB-0C1B-86AE-20EFCF3AC984}	Hep B, adolescent or pediatric (08)	09/12/2011	5 months 11 days (164 days)	1	Invalid Immunization	

Recommendations (# of Results: 1) — New

Recommended Vaccine	Date Due	Age @ Rec Date	Recommendation	Reason(s)	Delete
HepB (100)	11/07/2011	7 months 6 days (220 days)	Future Recommendation	Due in Future	

Expected Outputs

* **Date of Birth:** 04/01/2011 **Age @ Execution Date:** 6 months 20 days (203 days)

* **Execution Date:** 10/21/2011 **Set Execution Date @ Age:** Set

* **Gender:** Female (F)

Proof of Immunity/Documented Disease (# of Results: 0) New

Antigen	Immunity Date	Age @ Imm Date	Immunity Reason	Delete
No records found.				

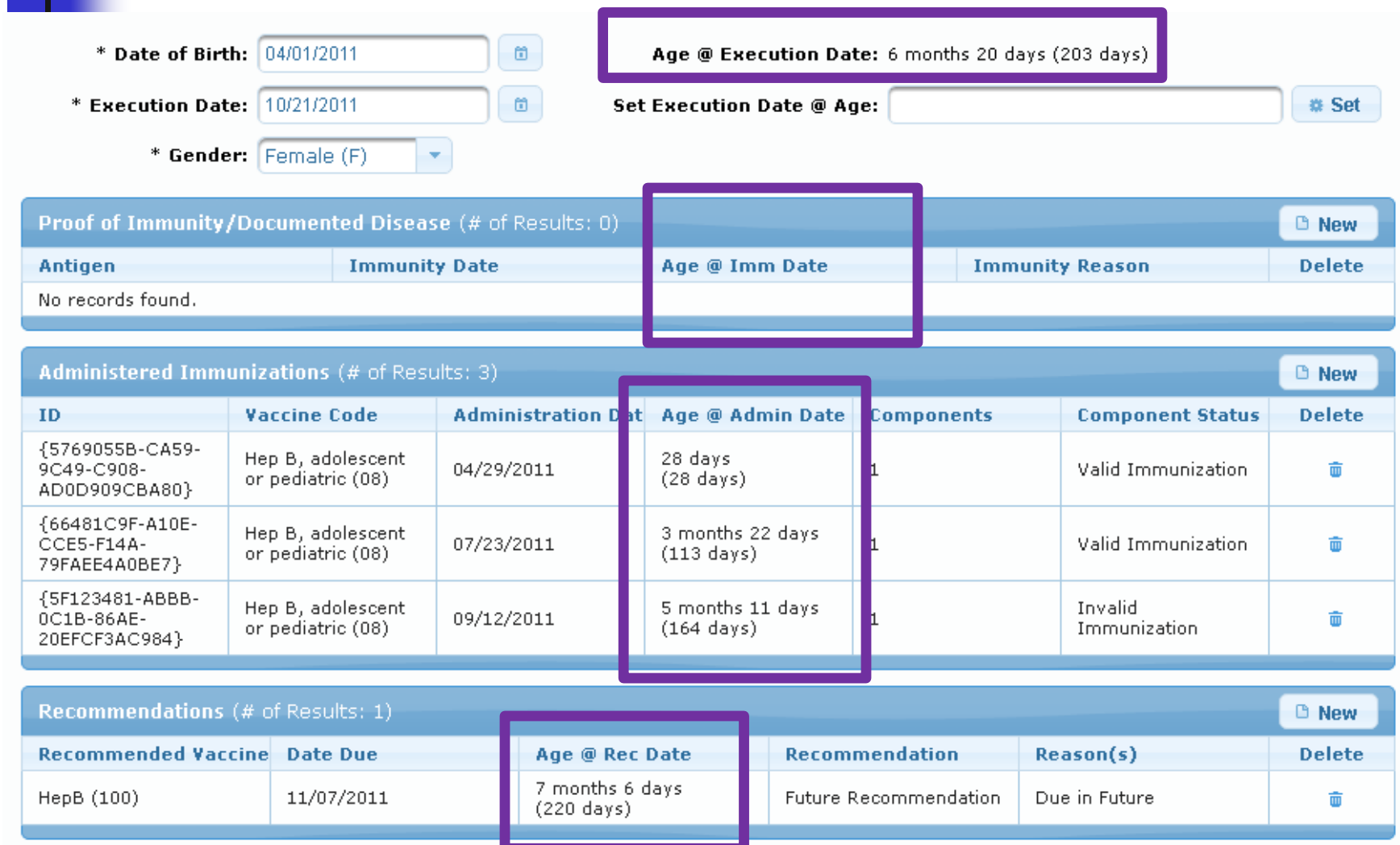
Administered Immunizations (# of Results: 3) New

ID	Vaccine Code	Administration Dat	Age @ Admin Date	Components	Component Status	Delete
{5769055B-CA59-9C49-C908-AD0D909CBA80}	Hep B, adolescent or pediatric (08)	04/29/2011	28 days (28 days)	1	Valid Immunization	
{66481C9F-A10E-CCE5-F14A-79FAEE4A0BE7}	Hep B, adolescent or pediatric (08)	07/23/2011	3 months 22 days (113 days)	1	Valid Immunization	
{5F123481-ABBB-0C1B-86AE-20EFCF3AC984}	Hep B, adolescent or pediatric (08)	09/12/2011	5 months 11 days (164 days)	1	Invalid Immunization	

Recommendations (# of Results: 1) New

Recommended Vaccine	Date Due	Age @ Rec Date	Recommendation	Reason(s)	Delete
HepB (100)	11/07/2011	7 months 6 days (220 days)	Future Recommendation	Due in Future	

Calculated Values



* Date of Birth: 04/01/2011

* Execution Date: 10/21/2011

* Gender: Female (F)

Age @ Execution Date: 6 months 20 days (203 days)

Set Execution Date @ Age: Set

Proof of Immunity/Documented Disease (# of Results: 0) — New

Antigen	Immunity Date	Age @ Imm Date	Immunity Reason	Delete
No records found.				

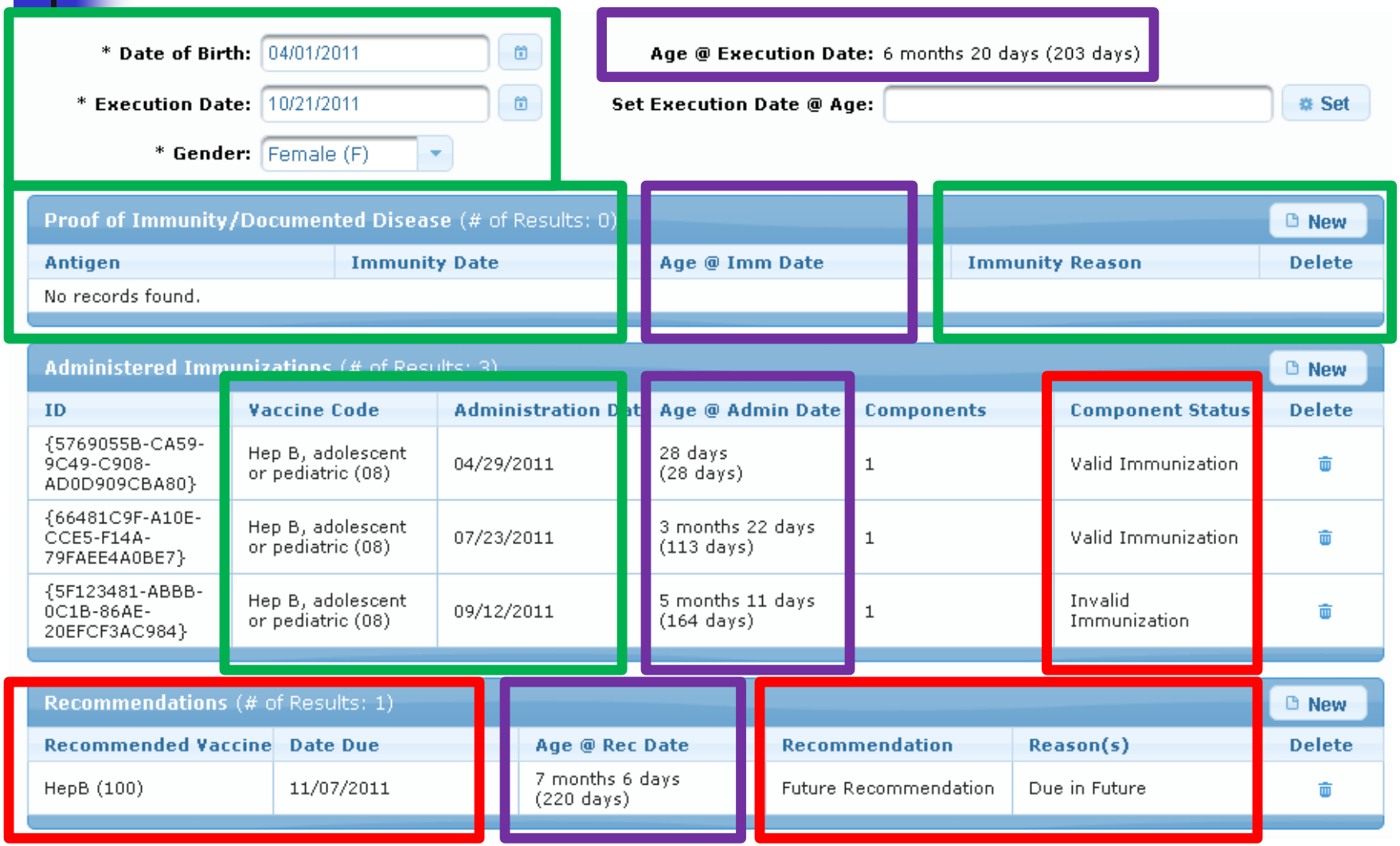
Administered Immunizations (# of Results: 3) — New

ID	Vaccine Code	Administration Dat	Age @ Admin Date	Components	Component Status	Delete
{5769055B-CA59-9C49-C908-AD0D909CBA80}	Hep B, adolescent or pediatric (08)	04/29/2011	28 days (28 days)	1	Valid Immunization	
{66481C9F-A10E-CCE5-F14A-79FAEE4A0BE7}	Hep B, adolescent or pediatric (08)	07/23/2011	3 months 22 days (113 days)	1	Valid Immunization	
{5F123481-ABBB-0C1B-86AE-20EFCF3AC984}	Hep B, adolescent or pediatric (08)	09/12/2011	5 months 11 days (164 days)	1	Invalid Immunization	

Recommendations (# of Results: 1) — New

Recommended Vaccine	Date Due	Age @ Rec Date	Recommendation	Reason(s)	Delete
HepB (100)	11/07/2011	7 months 6 days (220 days)	Future Recommendation	Due in Future	

Test Case Data (again)



* Date of Birth: 04/01/2011
* Execution Date: 10/21/2011
* Gender: Female (F)

Age @ Execution Date: 6 months 20 days (203 days)

Set Execution Date @ Age: Set

Proof of Immunity/Documented Disease (# of Results: 0) — New

Antigen	Immunity Date	Age @ Imm Date	Immunity Reason	Delete
No records found.				

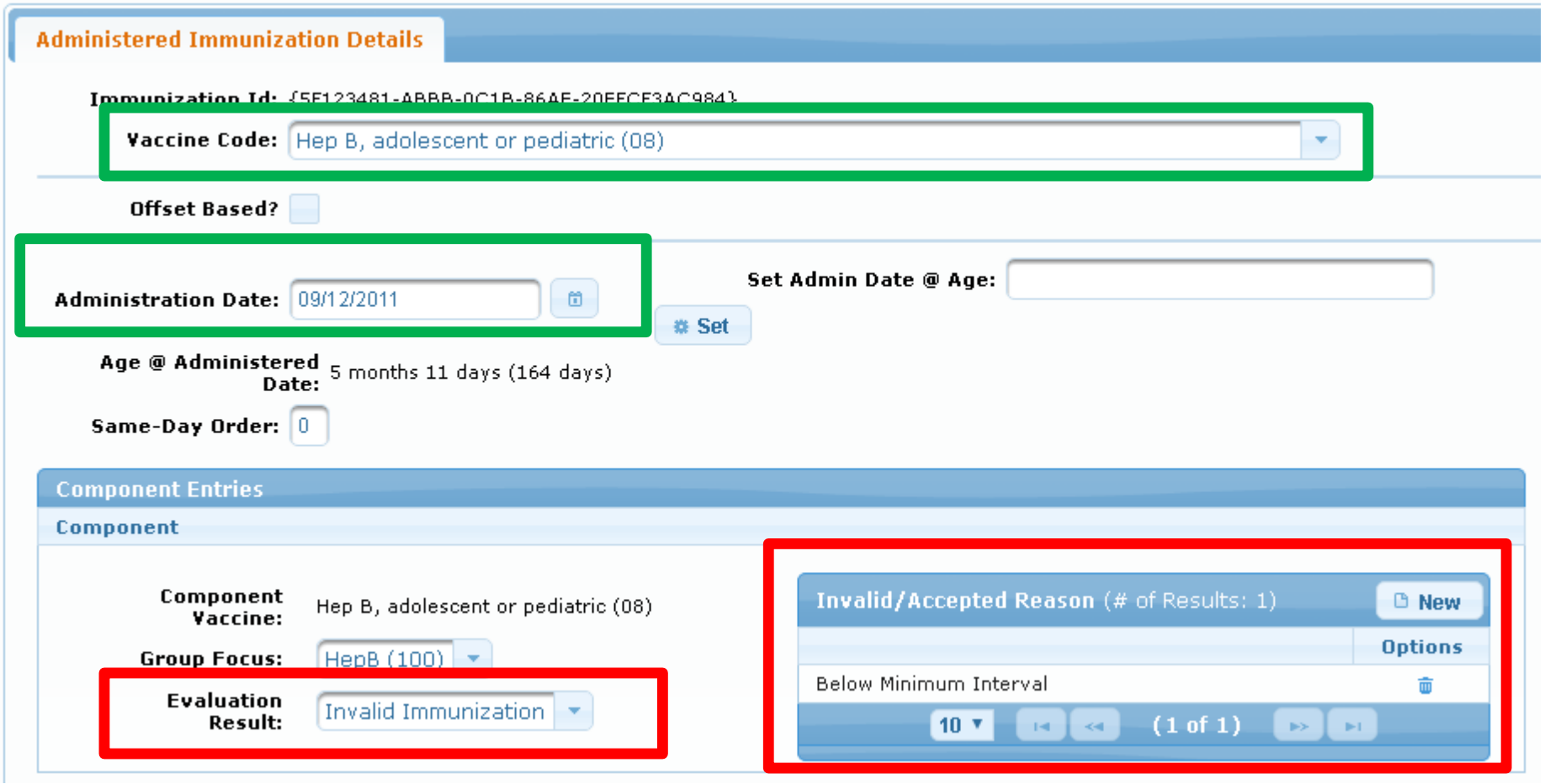
Administered Immunizations (# of Results: 3) — New

ID	Vaccine Code	Administration Dat	Age @ Admin Date	Components	Component Status	Delete
{5769055B-CA59-9C49-C908-AD0D909CBA80}	Hep B, adolescent or pediatric (08)	04/29/2011	28 days (28 days)	1	Valid Immunization	
{66481C9F-A10E-CCE5-F14A-79FAEE4A0BE7}	Hep B, adolescent or pediatric (08)	07/23/2011	3 months 22 days (113 days)	1	Valid Immunization	
{5F123481-ABBB-0C1B-86AE-20EFCF3AC984}	Hep B, adolescent or pediatric (08)	09/12/2011	5 months 11 days (164 days)	1	Invalid Immunization	

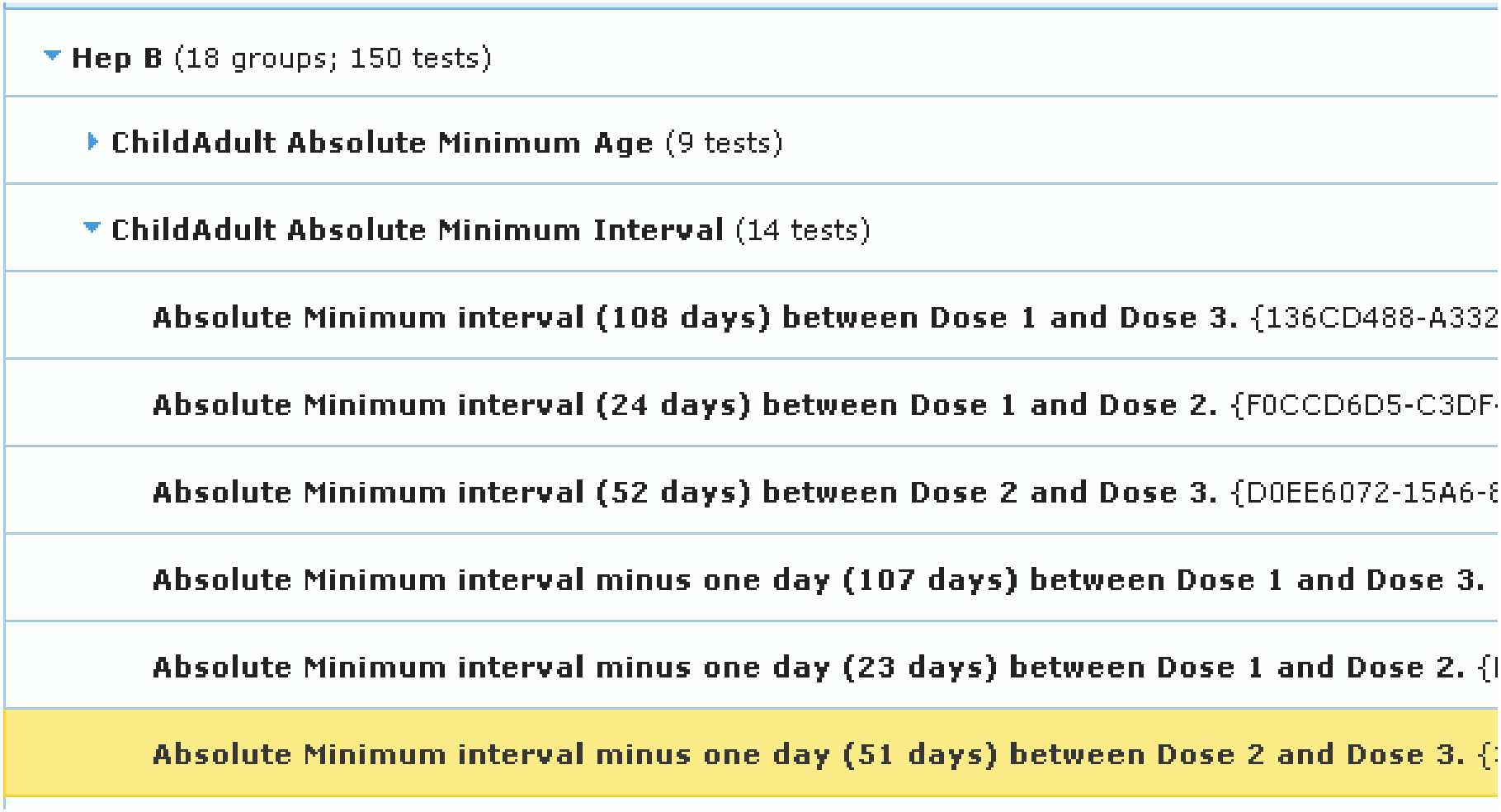
Recommendations (# of Results: 1) — New

Recommended Vaccine	Date Due	Age @ Rec Date	Recommendation	Reason(s)	Delete
HepB (100)	11/07/2011	7 months 6 days (220 days)	Future Recommendation	Due in Future	

Adding/Editing a Dose Administered



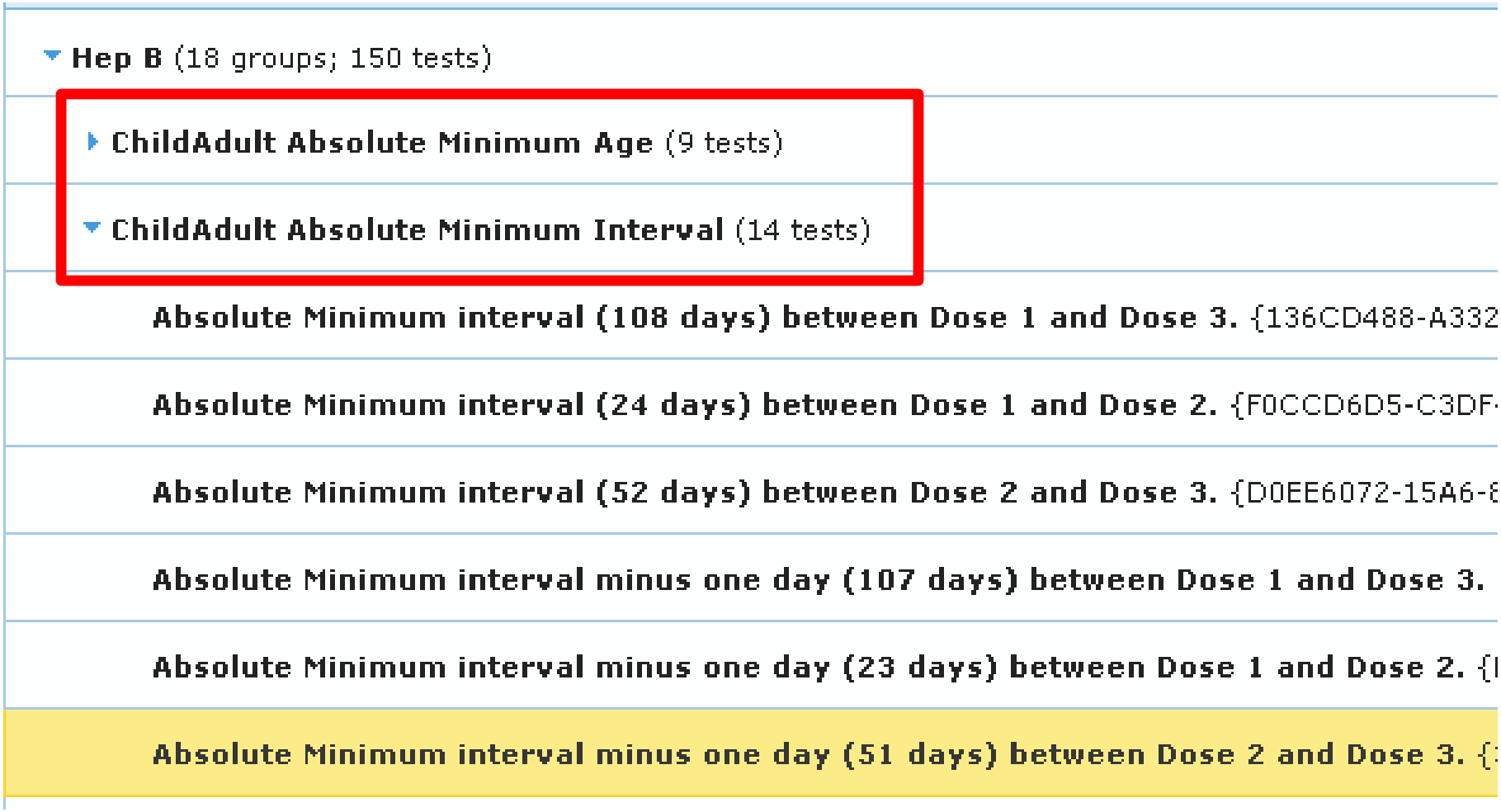
Heirarchical Grouping of Tests



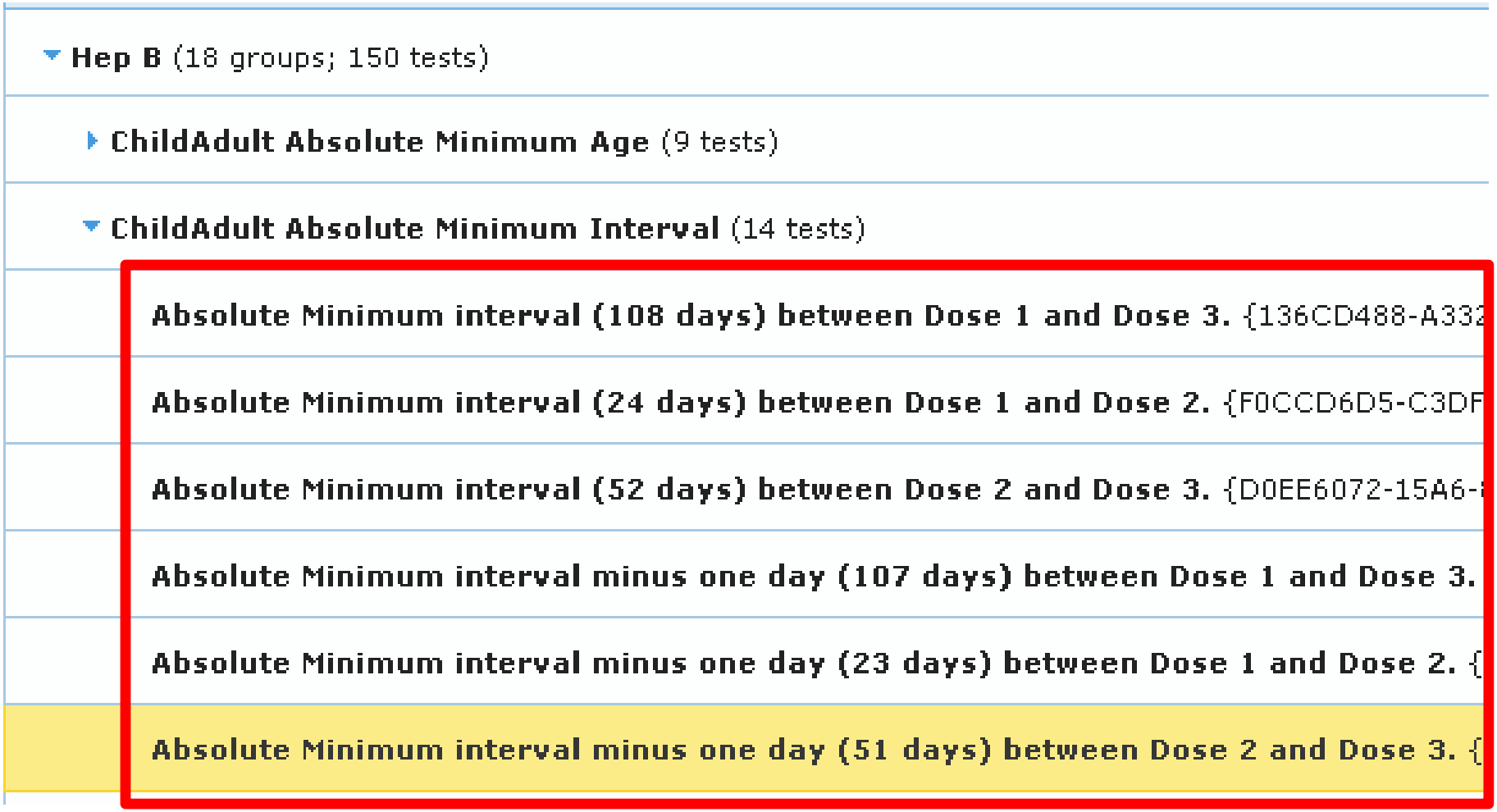
Top Level = “Suite” of Tests

- **Hep B** (18 groups; 150 tests)
  - **ChildAdult Absolute Minimum Age** (9 tests)
  - **ChildAdult Absolute Minimum Interval** (14 tests)
    - **Absolute Minimum interval (108 days) between Dose 1 and Dose 3.** {136CD488-A332
    - **Absolute Minimum interval (24 days) between Dose 1 and Dose 2.** {F0CCD6D5-C3DF
    - **Absolute Minimum interval (52 days) between Dose 2 and Dose 3.** {D0EE6072-15A6-8
    - **Absolute Minimum interval minus one day (107 days) between Dose 1 and Dose 3.**
    - **Absolute Minimum interval minus one day (23 days) between Dose 1 and Dose 2.** {
    - **Absolute Minimum interval minus one day (51 days) between Dose 2 and Dose 3.** {

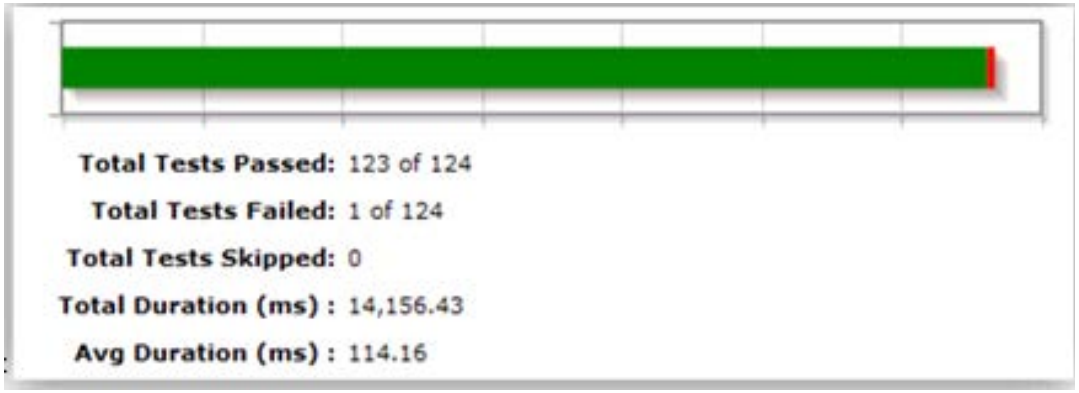
Middle Level = “Group” of Tests



Bottom Level = Individual Tests



Results of Automated Test Run



Suite Details | Suite Test Results

Suite Test Results for: HepB Tests

Expand rows to see detailed information

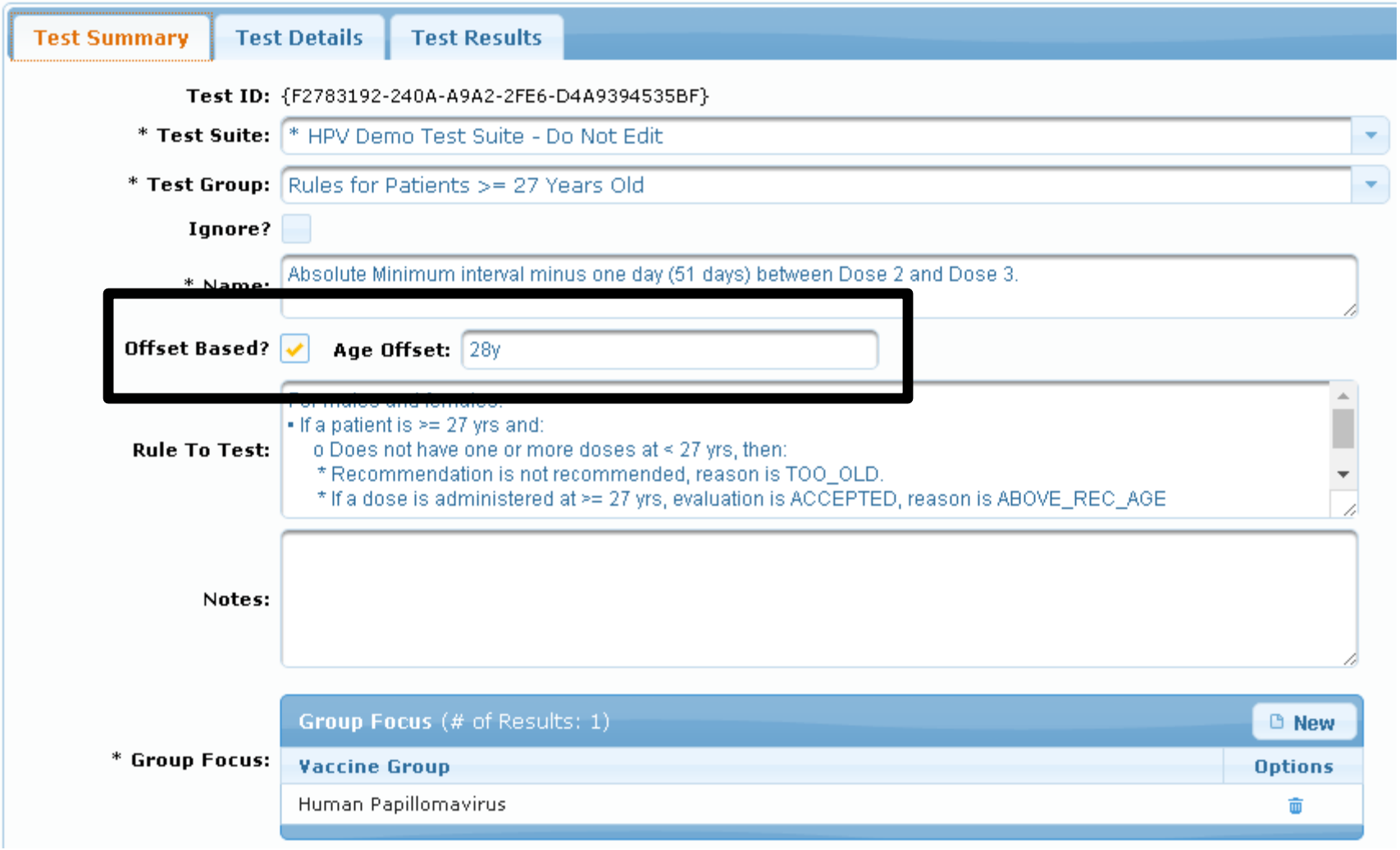
	ID	Name	Duration (ms)	Eval. Passed?	Rec. Passed?	Passed?
▶	72	Minimum interval minus one day (23 days) between Dose 1 and Dose 2.	97	✓	✓	✓
▶	73	Minimum interval (24 days) between Dose 1 and Dose 2.	115.39	✓	✓	✓
▼	74	Minimum interval plus one day (25 days) between Dose 1 and Dose 2.	93.18	✓	⊘	⊘
	Differences					
	Recommendation Date Due date values do not match: **ICE**=10/01/2011; **EXPECTED**=10/10/2011					
▶	75	Minimum interval minus one day (51 days) between Dose 2 and Dose 3.	96.92	✓	✓	✓

What Comes Next for CAT?

Two Approaches to Preventing Aging of Test Cases

- CAT Currently Supports
  - Fixed Assessment/Execution Date
  - Fixed Date of Birth
  - Fixed Dates of Administration
- Adding Support for 2nd Approach
  - Assessment/Execution Date = Today (Always!)
  - Fixed Age
  - Fixed Age at Administration, and/or
  - Fixed Interval at Administration

Patient has Fixed Age in this Test Case



Execution Date = Today (3/26/16) Date of Birth is Calculated

Test Summary | Test Details | Test Results

Date of Birth: 03/26/1988 **Age @ Execution Date:** 28 years (10227 days)

Execution Date: 03/26/2016

*** Gender:** Female (F)

Proof of Immunity/Documented Disease (# of Results: 0) — New

Antigen	Immunity Date	Age @ Imm Date	Immunity Reason	Delete
No records found.				

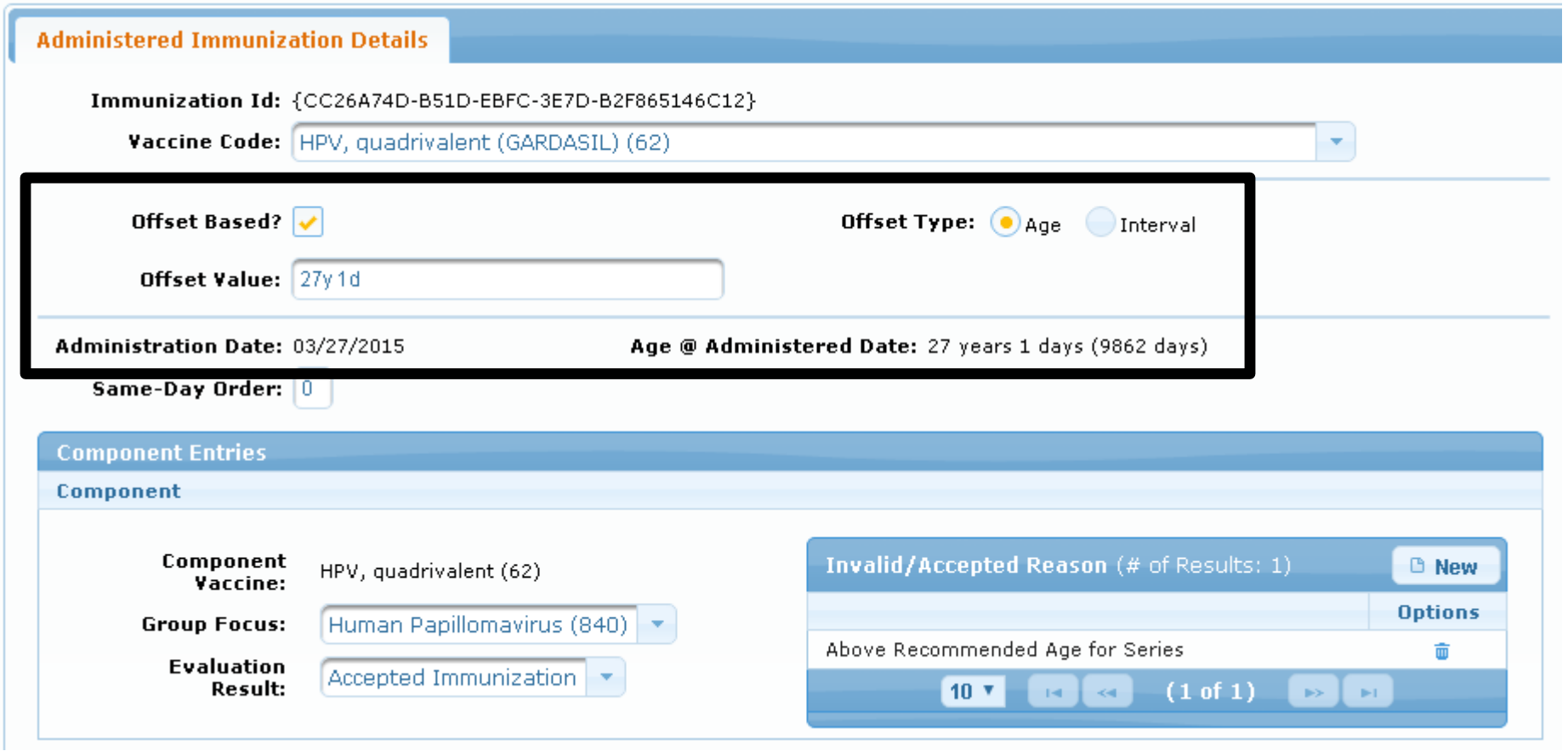
Administered Immunizations (# of Results: 1) — New

ID	Vaccine Code	Administration Dat	Age @ Admin Date	Components	Component Status	Delete
{CC26A74D-B51D-EBFC-3E7D-B2F865146C12}	HPV, quadrivalent (GARDASIL) (62)	03/27/2015	27 years 1 days (9862 days)	1	Accepted Immunization	

Recommendations (# of Results: 1) — New

Recommended Vaccine	Date Due	Age @ Rec Date	Recommendation	Reason(s)	Delete
Human Papillomavirus (840)	N/A	N/A	Not Recommended	Too Old	

Dose is Given at Fixed Age in this Test Case



Contact Us for More Information

Mike Suralik

856-751-1094

suralik@hln.com

URL: www.hln.com/ice

Email: ice@hln.com