Test Planning, An Integrated Approach

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1. Introduction

An integrated approach to test planning provides several advantages as opposed to a non-integrated approach. What is a non-integrated approach? Consider test campaigns where the test cards are written by one Flight Test Engineer (FTE) in one software program, the Test Hazard Analyses (THA) are perhaps written by the same FTE but in a separate program, the flight package (also referred to as test sequence or test card deck) is written in another program, the instrumentation parameter requirements are managed in another program, and the weight and balance planning is done by another FTE in yet another program or by hand. Now consider the several other documents and products that build up a test program and how many people are responsible for drafting them. In a larger flight test organization, that could easily be approaching a dozen people. For a smaller organization, the responsibility could rest entirely on one individual with a large workload and a lot to track, with the opportunity to inadvertently let details of various products slip through the cracks. The non-integrated test planning approach causes concerns with respect to the efficiency, quality and safety of a test program where schedule and program risk may be realized, or an unfortunate error in test planning can propagate to something larger during test execution.

Test and Evaluation organizations around the planet have realized that these are issues that can be solved with an integrated approach to test planning and have begun implementing either proprietary test planning software or taking advantage of commercially available solutions. These solutions essentially serve as risk mitigation towards the hazards associated with realized program risk or unforeseen issues that would otherwise propagate through the test planning process and become realized during test execution. One example of an integrated test planning platform aimed to solve these issues is Test Organizer and Manager (TOM) which has been developed and refined over the last several years, across a diverse spread of flight test programs by AeroTEC, Inc. The objective of this paper is to explore the reasons an integrated approach is not only beneficial but critical and show how TOM implements this integrated approach.

2. Introduction to TOM

TOM is an off-the-shelf adaptable application that can be used for any flight test campaign. TOM has been adapted and used on a variety of programs from clean sheet, multiple aircraft programs to small STC programs involving a single modification. AeroTEC has spent significant time over a diverse plethora of test campaigns using and improving this integrated approach to test planning through execution. TOM integrates test cards, THAs, instrumentation requirements, flight packages (also known as test card decks or test sequences), weight and balance, flight planning and reporting in a single software platform. The following sections will detail how all of these test planning facets are integrated, how that integration is implemented in TOM and why that integration is so beneficial to any flight test organization, large or small.

TOM uses a client-server architecture to allow multiple users to use and update the contents of a shared database. As each individual FTE updates test cards, risk assessments, test plans, et al, these updates are pushed to every other active TOM user, so that all users have the most current information. This has efficiency advantages over a typical file system, where FTEs may need to coordinate who is updating what and when, bottlenecking potential updates and introducing more opportunities for error, for example accidentally working off an older version of the file or forgetting to update the associated risk assessment or test plan. The relational database structure automatically keeps everything that references each other up to date, reducing the opportunities for an errant test artifact to be generated, thereby promoting safer testing and more efficient planning. For example, if a THA is updated to include additional mitigations, every other test card that referenced the updated THA is updated with that information, without the need for the FTE to go through every test card and update the same THA multiple times.

3. Test Planning Integration Benefits

An integrated test planning approach provides risk mitigation baked into the test planning process by keeping everything centralized in one place, which reduces the risk of inadvertent mistakes in the planning process that may otherwise become realized during a brief or test execution which is too late. By integrating all aspects of test planning in a platform such as TOM, an number of benefits are realized in almost all areas of the program. As an integrated approach, TOM provides an increase in test planning efficiency first in terms of the time saved in performing repetitive or complex tasks and when the same information is needed in multiple areas. Whether utilizing document templates in a non-integreated approach or entering information into TOM, the initial time it takes to draft content for test planning products will essentially be the same. The efficiency of an integrated approach is realized mostly when it comes time to integrate everything into a flight package for a given test where all of the same details are needed. The benefits are then multiplied as the number of test cards and flight packages increase due to the simplicity TOM offers when duplicating similar information. This approach improves quality at the same time as it ensures data consistency. TOM offers even further increases in efficiency in the flight planning phase by integrating weight and balance, test point and phase of flight duration and fuel planning into the flight package. TOM also integrates the safety planning (THAs & Safety of Flight (SOF) instrumentation requirements) into the same platform which ensures safety is considered for every test card and then guarantees the associated THAs developed are automatically incorporated into the flight package for the day of test. The following sections will detail the specific benefits of an integrated test planning approach as well as explore the way TOM has implemented this integrated approach.

3.1. Test Cards, Test Conditions & Flight Packages

Drafting a test card and assigning associated instrumentation parameter requirements, THA's, and test conditions to that test card, occur in the same area of TOM (Figure 1).

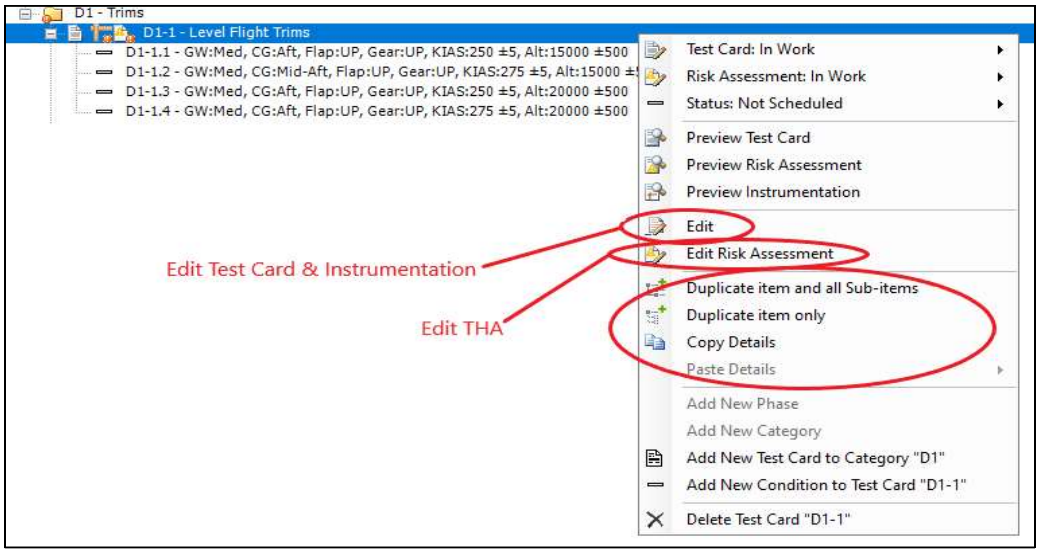


Figure 1 Test Condition Tree and Menu

This is where the integration begins; to keep everything in one place versus multiple documents or software programs. Multiple high level groupings (phases) may be used to differentiate between test program phases such as company and certification phases. Within those phases, different categories may be used to further organize test cards as shown in Figure 2. This organization and integration framework is critical to keeping track of the entire test program and allows anyone to quickly find any test card, THA or instrumentation list and its status.

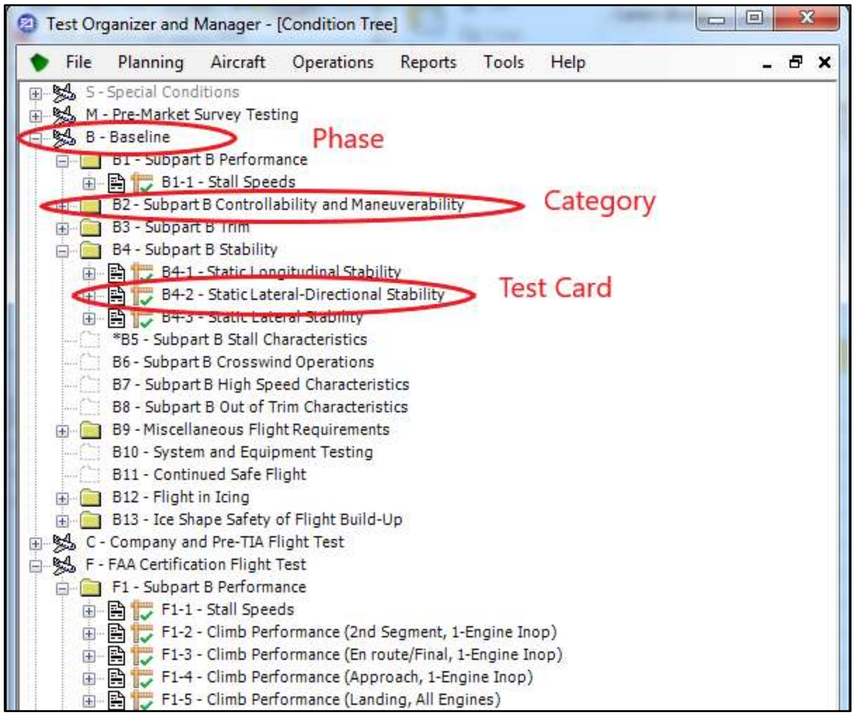


Figure 2 Test Condition Tree (Phases, Categories and Test Cards)

When preparing for a test, the test cards are typically populated first. In TOM, the test procedure details, associated requirements (references), pre-requisites, instrumentation and even attachments and equipment are entered from the same screen as shown in Figure 3 below. By integrating all of this, it not only saves time during the input stage because it's no longer necessary to pull up several different documents but it also saves time during the review and approval stage since it can all be approved together instead of having to route, review and approve multiple documents.

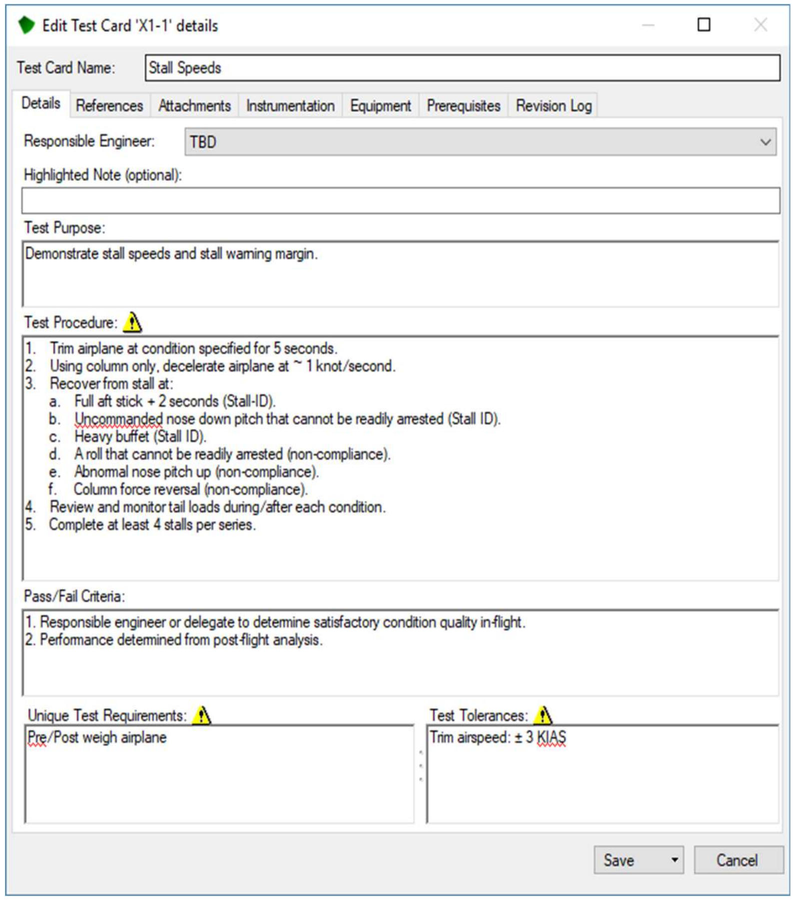


Figure 3 Test Card Editor

TOM also allows integration of regulations and requirements that the test card is designed to address. This is done in the reference tab of the test card editor (Figure 3 above). This allows for the purpose of the test card to be clear by association, and includes all the references in the shared database, rather than needing to be managed in an external artifact. Without such integration, managing the relationship between test cards and conditions to requirements would require extensive updating as well as constant visibility on new or revised test conditions. Failure to properly manage this could result in test conditions not being scheduled and executed in a timely manner which could easily lead to schedule delays especially if the configuration of the aircraft has changed or if that test condition was a prerequisite for another test campaign.

All test cards, THAs and instrumentation requirements are revision controlled in order to prevent unauthorized or inadvertent changes since any change has the potential to impact safety. Details of the revision control such as who authored each revision level, who reviewed and who approved as well as related notes can be found in the Revision Log tab of the test card editor (see Figure 3 above). By controlling the revisions, it prevents edits from being made without the awareness of the author or test crew. This revision control is also integrated into the flight package by providing a warning on the first page if the flight package includes an unapproved test card or THA (reference Figure 5 below). Without this integration, there could be a situation where a test card is in the process of being revised and the wrong revision is included in a flight package which could lead to an inefficient test or worse.

Many test cards share common attributes, such as THAs or required instrumentation. TOM provides the user with the ability to copy and paste this content from test card to test card. The menu selections for this can be seen in Figure 2 above. This improves quality by reducing the opportunities for human input error when manually copying material from one test card to another. It also improves safety when you consider the following scenario. If one test card has a long list of required instrumentation for monitoring and the same instrumentation list is required for another test card, missing a required parameter on a test card could lead to a test condition being performed with inadequate safety monitoring which in the worst case could lead to a safety incident or accident. Another case to consider is if a risk assessment on a test card is updated and that same risk assessment is applicable to tens of other test cards. Rather than having to manually update every individual risk assessment, it can simply be copied and pasted to the relevant test cards. In addition to copying specific data from test card to test card, test cards and conditions can also be duplicated in their entirety making it very easy to create identical company and certification conditions, for example, or to copy a test card to create an easier starting point for a similar test card.

After the test cards are created, test conditions from any test card can then be pulled into a flight package. All information from the associated test card and test condition is automatically imported into multiple sections of the flight package. One of the biggest advantages to this integration is during the flight planning phase. In the Flight Editor view of TOM, all the test condition data (GW, CG, altitude, airspeed, config, time required, etc) for all the selected conditions for that test is presented in a table format. This can be seen in Figure 4 below. Conditions can be easily re-ordered by dragging and dropping, making it easy to visualize and optimize the sequence. Without this integration, test card procedures and test condition details would have to be manually copy/pasted from various individual test plan documents into different sections of the flight package which is very labor intensive. On top of that, it becomes even more labor intensive when re-ordering conditions to optimize the sequence because all of the copy/pasting has to be repeated every time which creates an opportunity for error if copy/pasting was completed for one section but not another. Tasks that are labor intensive and create opportunities for error make the traditional approach inefficient thus the need for integration.

Sequence | W&B - BEW | W&B - Ballast | CG Management

	Condition	Minutes	Altitude Start (ft)	Altitude Reference	Altitude Delta (ft)	Airport	Burn Type	Fuel Burn (lb/hr)	Fuel Used (lb)	Fuel Remaining (Wing Tanks | Center Tank)	ZFW (lb)	ZFCG (%MAC)	GW (lb)	CG (%MAC)	Group
										15132 | 0	23666	26.90	38798	29.67	Preflight Ram
1	S1-3.1	0.0	0	AGL	0	KMWH	Wings	None	0	15132 | 0	23666	26.90	38798	29.67	APU On
2	S1-2.1	2.0	0	AGL	0	KMWH	Wings	Taxi	17	15115 | 0	23666	26.90	38781	29.65	Engine Start
3	S1-4.1	0.0	0	AGL	0	KMWH	Wings	None	0	15115 | 0	23666	26.90	38781	29.65	APU Off
4	S1-1.1	1.0	0	AGL	0	KMWH	Wings	Taxi	8	15107 | 0	23666	26.90	38773	29.64	Control Swee
5	S2-1.1	10.0	0	AGL	0	KMWH	Wings	Taxi	83	15024 | 0	23666	26.90	38690	29.55	Taxi
6	B2-2.4	3.0	0	AGL	500	KMWH	Wings	Takeoff	275	14749 | 0	23666	31.19	38415	31.90	Takeoffs with
7	S2-3.1	2.9	1689	Hp	4311	KMWH	Wings	Climb	240	14509 | 0	23666	31.19	38175	31.65	Climb
8	B4-1.1	6.0	**6000**	Hp	4000	KMWH	Wings	Climb	500	14009 | 0	23666	31.19	37675	31.13	Static Longitu
9	S2-3.1	1.3	10000	Hp	2000	KMWH	Wings	Climb	111	13898 | 0	23666	31.19	37564	31.02	Climb
10	B4-1.3	10.0	12000	Hp	0	KMWH	Wings	Cruise	367	13531 | 0	23666	31.19	37197	30.66	Static Longitu
11	B4-1.6	6.0	**12000**	Hp	0	KMWH	Wings	Cruise	220	13311 | 0	23666	31.19	36977	30.41	Static Longitu
12	B4-1.2	10.0	12000	Hp	0	KMWH	Wings	Cruise	367	12945 | 0	23666	31.19	36611	30.16	Static Longitu
13	S2-3.1	1.3	12000	Hp	2000	KMWH	Wings	Climb	111	12834 | 0	23666	31.19	36500	30.14	Climb
14	B4-2.4	4.0	14000	Hp	0	KMWH	Wings	Low Speed	100	12734 | 0	23666	31.19	36400	30.12	Static Lateral
15	B4-3.4	**0.0**	14000	Hp	0	KMWH	Wings	Low Speed	0	12734 | 0	23666	31.19	36400	30.12	Static Lateral
16	B4-2.5	4.0	14000	Hp	0	KMWH	Wings	Low Speed	100	12634 | 0	23666	31.19	36300	30.11	Static Lateral
17	B4-3.5	**0.0**	14000	Hp	0	KMWH	Wings	Cruise	0	12634 | 0	23666	31.19	36300	30.11	Static Lateral

Figure 4 Flight Editor-Sequence

When planning a series of tests, flexibility to quickly modify multiple flight packages is an important feature of TOM and an added benefit to the integration. This allows the FTE to quickly pivot conditions from one test to another when not all conditions can be completed in the initial test or just need to be moved or copied for another reason. This improves efficiency in turnaround time for the next test. Without integration, the flight package would have to be reworked manually, requiring a significant amount of time copying all the test card, test condition and THA data into all the necessary sections, reformatting and then recalculating the time and weight and balance planning. With this integration, it's a simple drag and drop with only minimal time required to view the impact of the change and refine the updated flight package.

Once the order of conditions is optimized and all other details for the test are input, the flight package can then be exported into a document format to be used during the test. The document is automatically formatted which saves a tremendous amount of time compared to manually copying the individual information into several sections of the flight package. Each test procedure and set of conditions are formatted on to their own pages and the pages are ordered by the planned flight sequence (or other desired order) to make it user friendly to the test crew. The altitude and time per condition is plotted on a flight profile chart on the cover page (Figure 5) to give the crew a great visual of the flight which aids in flight planning. Without this integration, it would require a separate effort and yet again more planning time. The condition details (GW, CG, altitude, airspeed, config, etc) are populated on a sequence page (Figure 6) which gives a quick summary of the order of conditions and the differences between the conditions. All the above-mentioned data import functions are done automatically as compared to the enormous amount of time it would take using individual documents that are not integrated making this integration critical to an efficient test program.

AeroTEC

Flight Release Form

(Test Title Goes Here)

Flight 6 - Flight Loads Survey #3

Weight & Balance		
ZFW:	418,952	lb
ZFCG:	16.29	%MAC
Ramp GW:	661,972	lb
Ramp CG:	19.82	%MAC

Fuel Load		
Wings:	138,020	lb
Center:	105,000	lb
Total:	243,020	lb

Crew Manifest

Name	Location
(Crew Names)	Pilot
	Copilot
	1st Observer
	2nd Observer
	DAS Rack 1
	DAS Rack 2
	Fwd Analyst Rack 1
	Fwd Analyst Rack 2
	Aft Analyst Rack 1
	Aft Analyst Rack 2

Flight Release

Maintenance

I certify that required maintenance is complete and the aircraft is airworthy for the purpose of flight testing.

Ground Operations

I certify that the aircraft has been fueled and loaded in accordance with the manifest.

Instrumentation

I certify that required flight test instrumentation is ready for the planned test. All instrumentation deviations have been briefed.

Test Director

I certify that the aircraft is in the correct configuration for test, and that all planned test conditions have been briefed to the flight crew.

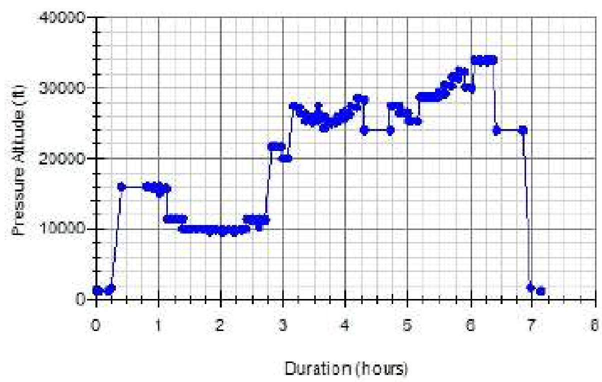
Pilot in Command

I have reviewed the maintenance, instrumentation, and manifest and agree that the aircraft and crew are ready for test.

FAA/DER (as req'd)

I certify that the aircraft is ready for the certification flight test.

Highest Residual Risk:	Med
Airport(s):	KMWH
Max Planned Pressure Alt:	34000 ft
Expected Landing Weight:	509600 lb (>MLW)
Validation Status:	Valid Sequence
Approval Status:	Contents Fully Approved
Scheduled Start:	2021/07/13 14:00
Estimated Duration:	7.1 hours



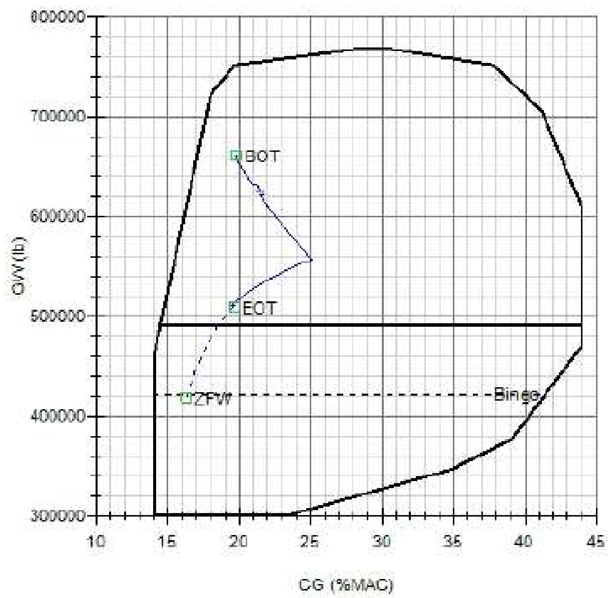


Figure 5 Flight Package Cover Page

Flight 25 - Company CDL Dispatch Aft CG Stability and Control #2

CG Management

Triggers are sorted in the order predicted to occur, but may occur in a different order depending on fuel burn and test condition durations.

~Time Elapsed	Trigger	Action	New ZFW/ZFCG (lb / %MAC)	Approx GW/CG (lb / %MAC)
☐ 0:00	On Ramp	Set Fuel Burn: Center	118888 / 33.34	127388 / 31.27
☐ 0:16	Before sequence #7	Move ballast items: 18 Lead bags (450) lb from Galley 2 (150.20 in) to Galley 4B (1220.00 in)	118888 / 35.94	125632 / 34.39
☐ > EOT	When "Center" fuel tank = 0 lb	Set Fuel Burn: Wing	118888 / 35.94	122888 / 35.44
☐ > EOT	When Gross Weight = 120000 lb	Move ballast items: 18 Lead bags (450) lb from Galley 4B (1220.00 in) to Galley 2 (150.20 in)	118888 / 33.34	120000 / 33.21

Test Sequence

Seq	Cond	Group	Altitude (ft)	KIAS	KCAS	Flaps	Gear	Airbrakes	Thrust	Notes
1	S1-3.1	APU On								
2	S1-2.1	Engine Start	0 AGL			OPT	DN			
3	S1-1.1	Control Sweeps	0 AGL			OPT	DN			Elevator, Ailerons, Rudder, Spoilers
4	S2-1.1	Taxi	0 AGL			UP	DN			
5	S2-2.1	Takeoff	0 AGL			OPT	DN			
6	S2-3.1	Climb				UP	UP			
7	F15-8.3	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	UP	UP		Idle	
8	F15-8.4	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	UP	UP	Ext	Idle	
9	F15-8.5	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	1	UP		Idle	
10	F15-8.6	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	10	UP		Idle	
11	F15-8.7	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	25	UP		Idle	
12	F15-8.8	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	30	DN		Idle	

Figure 6 Test Sequence in Flight Package

3.2. Test Hazard Analyses

Test cards are also integrated with THAs. The THAs are directly linked to the test card which are then integrated into the flight package. Anytime a condition is included in a flight package, the flight package will automatically include all the associated THAs. This is much easier than manually copy/pasting the associated THAs into the flight package from potentially multiple documents. It also ensures a THA is not inadvertently missed which could in the worst-case lead to a safety incident if a THA is not included and as a result, mitigations are not followed. Since the THAs are integrated into the same database, TOM also offers the option to automatically consolidate THAs in the event that the same THA is used for multiple procedures (Figure 7).

Exceeding Airspeed Limitations ...(BLF1-3, BLF1-4, BLF1-6, BLF3-2)

Applicable Test Card Numbers

Cause:

- Excessive nose down pitch attitude or bank angle
- Improper control input
- Failure to reduce thrust
- Poor atmospheric conditions

Risk Assessment: - - · Initial —— Residual

Avoid	High	High	Med	Low	Catastrophic
Avoid	High	Med	Med	Low	Hazardous
High	High	Med	Med	Low	Major
Med	Med	Med	Low	Low	Minor
Low	Low	Low	Low	Low	No Safety Effect
Frequent	Probable	Occasional	Remote	Improbable	

Effect:

Structural damage

Mitigations:

- Maneuver to be performed by pilot experienced with these maneuvers.
- Review standard WUT recovery procedures prior to flight, including thrust reduction during recovery.
- Pilot monitoring to call for recovery if pitch attitude exceeds 30° nose up, 15° nose down, or 70° of bank.
- Pilot monitoring to call "airspeed" when speed exceeds target by +5 KIAS or more
- Do not excessively unload wings or retract speedbrakes to initiate WUT recovery
- Monitor for temperature inversions during climb to altitude for possible overspeed conditions.

Emergency Procedures:

- 1. RTB if airspeed limits are exceeded during a test run.
- 2. If damage is suspected, a controllability check should be conducted prior to landing.

Figure 7 THA Page with Applicable Test Cards

In addition, anytime a test card is revised, the THA approval is also removed, forcing the author to consider whether the THA should be updated because of the test card change. THAs also have the ability to be refined at a condition level in case specific causes, effects or mitigations are only applicable to certain conditions within a test card (Figure 8). This allows the flight package to pull in only the THA details that are pertinent to the given test and leaves out details that are not applicable based on the planned conditions.

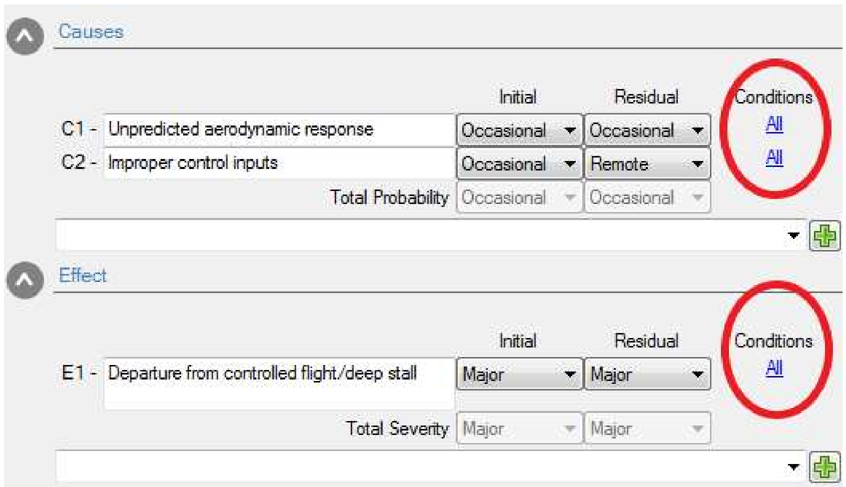


Figure 8 THA Edit Screen

When THA sections are edited, TOM ensures consistency across all THAs by automatically offering to apply the new wording to all similar THA phrases. It also saves the phrase so that when a new THA is created, the user has the option to select the exact same phrase so it saves time searching through all the documents trying to figure out which wording is the latest and greatest. This is especially important when a discovery is made and a mitigation needs to be modified in order to be more effective. Without this integration, it would be extremely time consuming to search all documents for similar situations and update each document individually. Without this integration, it would be easy to miss the incorporation of the same update in all other documents that have a similar situation which in the worst case may cause the test team to encounter the same issue in a subsequent test because they were not following the most effective mitigation

3.3. Instrumentation

TOM provides an environment to track instrumentation parameters for test equipment installed on the test article. Each instrumentation parameter would be assigned a Global Unique Identifier (GUID) number and can be defined in TOM by the type of measurement (accelerometer, force load cell, strain gage, thermocouple, or as defined by the user), range, accuracy, sample rate, units, et cetera. This instrumentation parameter list can be exported as its own document providing the flight test team with an Instrumentation Specification document. With each instrumentation parameter on the test article so defined, the user can then assign critical instrumentation used to analyze each of the maneuvers specified in the test cards, which is important for planning purposes to ensure that the required instrumentation is functional and ready for the planned maneuvers of a specific test event.

Instrumentation parameters are integrated within the test cards which are then integrated into the flight package. For each test card, the associated instrumentation parameters are selected and can be further classified at the condition level (Figure 9).

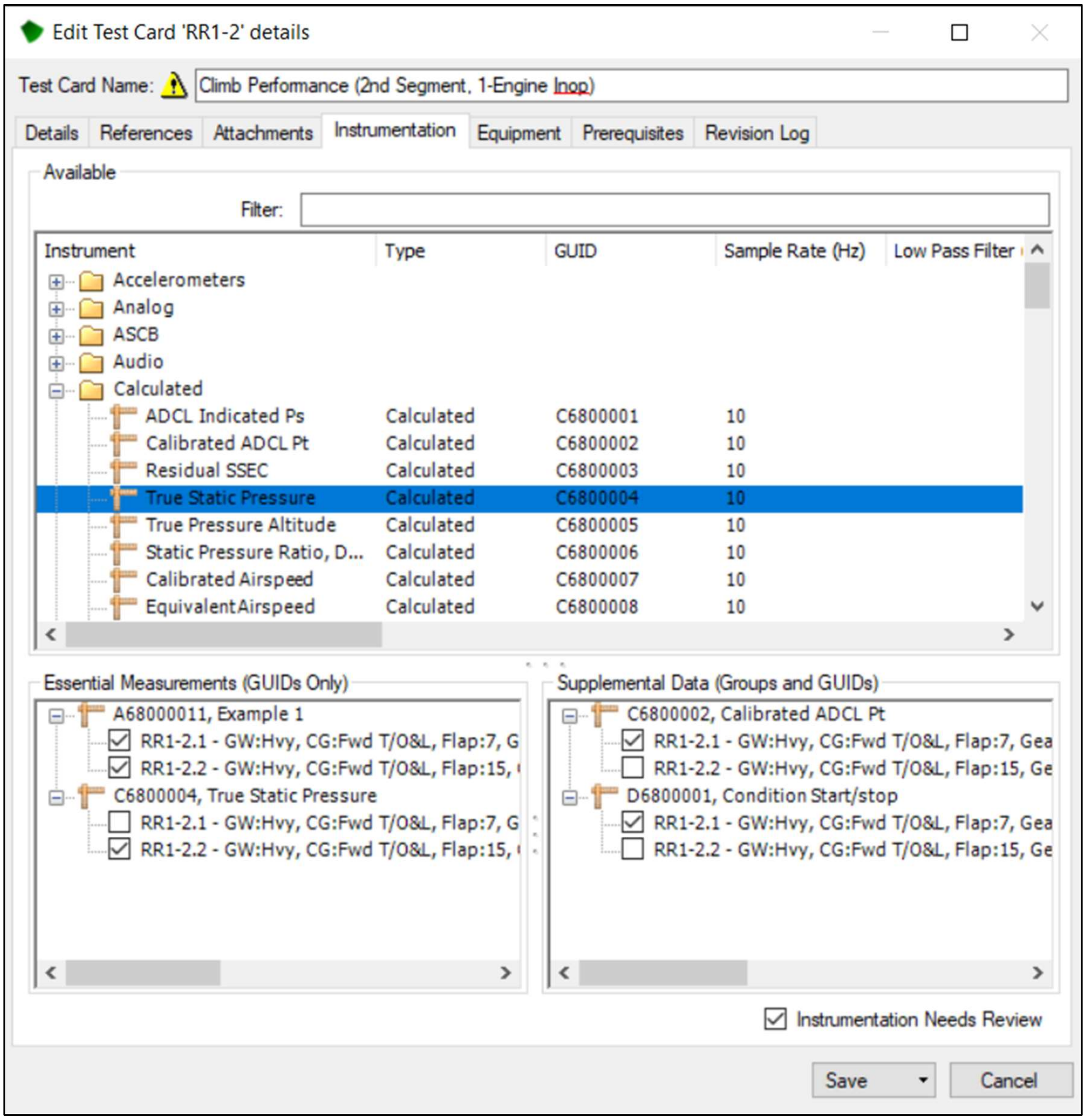


Figure 9 Instrumentation Parameter Requirement Input

For each condition or test card, there is the ability to select a parameter as essential or supplemental which allows the user to consider the bare minimum instrumentation requirements early in the planning process rather than having to make a last minute decision. It also helps the team prevent spending too much time troubleshooting a parameter that may only be supplemental without even having to make a phone call since it’s already spelled out. Once this is done and a condition is put into a flight package, the flight package then automatically generates a test specific table of required instrumentation parameters (Figure 10).

Instrumentation Applicability Summary

The tables below list all instrumentation which is essential ("E"), supplemental ("S"), or required for risk mitigation ("R") for New Flight

	N28478 Status at 2018/05/01 10:03	C1-1	C1-2	C1-3	C1-4	C1-5	C2-1	C2-2	C2-3	C2-4	C2-5	C2-6	C2-7	C2-8	C2-9	C2-10	C2-11	C2-12
A3790003 (Nz @ CG, g)	Removed										E							
A3790005 (Nz Pilot Seat, g)	Calibrated										S	S						
S3790003 (Pilot Column Force, strain)	Calibrated																	
S3790004 (Copilot Column Force, strain)	Calibrated																	
Analog\Force and Load\Tail Loads Strain Gages	Calibrated																	S
S3790101 (Stab Jackscrew Gimbal Load (Main), strain)	Calibrated	E																
S3790102 (Stab Jackscrew Gimbal Load (Spare), strain)	Calibrated	E																
S3790103 (L Stab Support Load (Main), strain)	Calibrated	E																
S3790104 (L Stab Support Load (Spare), strain)	Calibrated	E																
S3790105 (R Stab Support Load (Main), strain)	Calibrated	E																
S3790106 (R Stab Support Load (Spare), strain)	Calibrated	E																
X3790001 (Beta Vane, °)	Calibrated															S	S	S
E3790001 (Wheel Speed Left Outbd, V)	Not planned									S								
E3790002 (Wheel Speed Right Outbd, V)	Not planned									S								
B3790003 (Computed Airspeed - L, kts)	Valid	S					E	E	E				E	E	E	E	E	E
B3790005 (Mach - L)	Valid																	E
B3790006 (SAT - L, °C)	Valid	E	E	E	E	E												

Figure 10 Flight Test Package Instrumentation Page

The traditional approach of having separate and possibly multiple instrumentation parameter lists for the program would require a significant amount of time to sort through the list and identify which parameters were required for a given test then manually copy those parameters into the test specific required instrumentation list. This exercise would potentially have to be repeated for every single different procedure that was planned for that flight which could take even more time and also increases the chances that an error is made during the manual copy/pasting or in the research of the list itself (missing a parameter). The integrated approach does all of this automatically, drastically improving efficiency, quality and could even prevent a safety incident in the event that a SOF parameter was missed.

Another advantage to the integrated approach is that every time a test card is revised, there is an opportunity to revise the instrumentation requirements. This is a much more efficient approach over the traditional way in that multiple documents don't have to be opened and revised and that the instrumentation section is displayed right next to the test card which serves as a reminder and forces you to consider if there are instrumentation changes associated with the test card change.

The status of individual instrumentation parameters can also be managed within TOM. Parameters can be marked as operational or inoperative and that status will then show up in flight packages so it is obvious whether the required instrumentation is functional for that test (Figure 11 and Figure 10). This saves a lot of time versus managing the parameter status elsewhere as it eliminates the need for cross-checking the list of required parameters to the overall instrumentation status list.

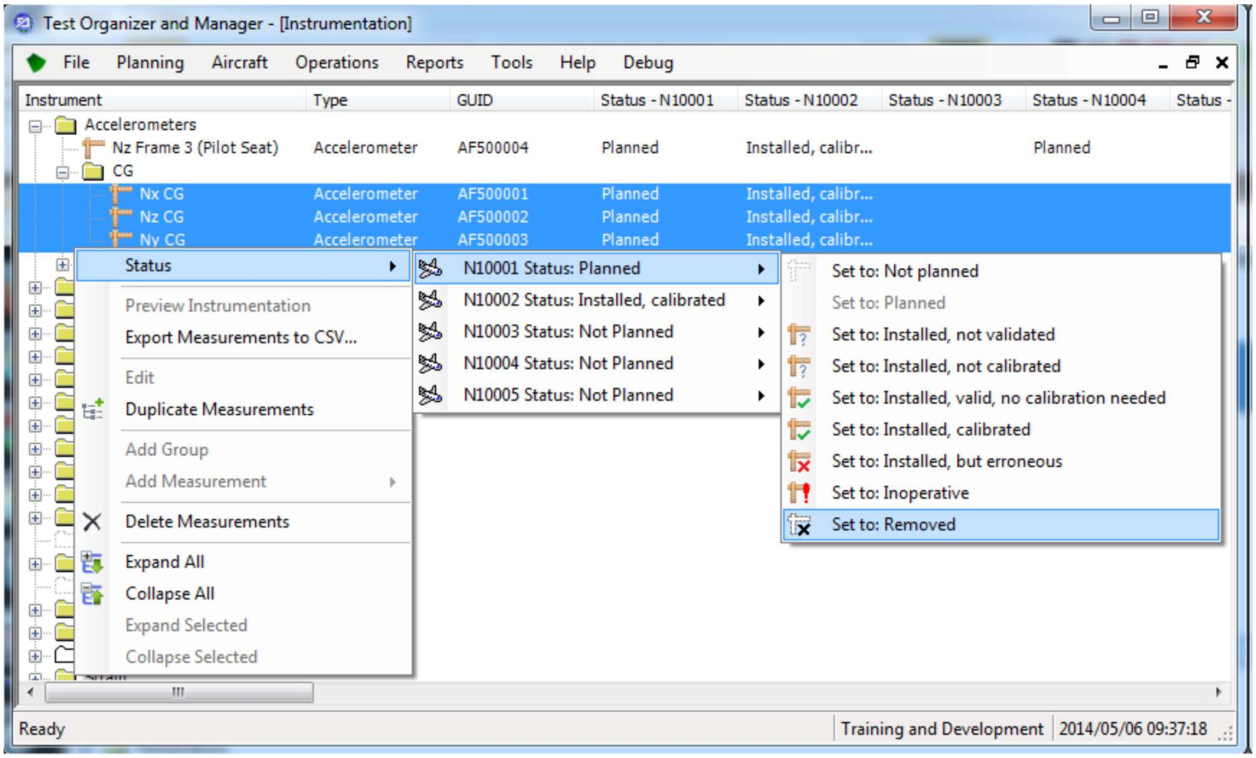


Figure 11 Managing Flight Test Instrumentation

3.4. Weight & Balance

TOM includes some basic but crucial weight and balance tools which aid the FTE in flight planning. With a Basic Empty Weight (BEW) as a starting point, equipment changes, ballast changes, initial fuel load, fuel burn, and crew changes, are all incorporated into flight weight and CG calculations. This improves safety in the predictability and confidence in the aircraft's configuration within the CG envelope of the plane for the duration of the planned flight. Without these built-in calculations, the FTE would have the additional workload of calculating the weight and balance of the aircraft at every test point, which is an additional opportunity for human error. By building these into the flight planning software, TOM gives the FTE the bandwidth to focus on the higher levels of planning (condition ordering, etc).

Fuel burn curves for the aircraft are used by TOM and aid the FTE in their flight planning. Each test condition specifies an expected burn configuration and duration, and with this information, TOM calculates and maintains the expected fuel quantities at every point in the sequence and provides warnings when the GW or CG extends outside of the designated flight envelope. This relieves the FTE of having to calculate the expected fuel remaining and CG at every point in the sequence and having to reference the envelope to see if the plan is still within the envelope. This is presented in the flight package for quick reference during the flight (see Figure 12 below). In the scenario of an updated starting fuel load, TOM recalculates the whole sequence instantly, whereas in more manual methods, the recalculation could take magnitudes of time longer, especially with manual verification methods. This improves the safety and efficiency of the test planning in regards to GW/CG management.

Fuel burn curves of experimental aircraft can require ballast transfers at critical moments during a test. TOM aids with the planning aspect of flights by including CG management actions in the flight sequence, as shown in Figure 12 below.

Flight 25 - Company CDL Dispatch Aft CG Stability and Control #2

CG Management

Triggers are sorted in the order predicted to occur, but may occur in a different order depending on fuel burn and test condition durations.

	~Time Elapsed	Trigger	Action	New ZFW/ZFCG (lb / %MAC)	Approx GW/CG (lb / %MAC)
☐	0:00	On Ramp	Set Fuel Burn: Center	118888 / 33.34	127388 / 31.27
☐	0:16	Before sequence #7	Move ballast items: 18 Lead bags (450) lb from Galley 2 (150.20 in) to Galley 4B (1220.00 in)	118888 / 35.94	125632 / 34.39
☐	> EOT	When "Center" fuel tank = 0 lb	Set Fuel Burn: Wing	118888 / 35.94	122888 / 35.44
☐	> EOT	When Gross Weight = 120000 lb	Move ballast items: 18 Lead bags (450) lb from Galley 4B (1220.00 in) to Galley 2 (150.20 in)	118888 / 33.34	120000 / 33.21

Test Sequence

Seq	Cond	Group	Altitude (ft)	KIAS	KCAS	Flaps	Gear	Airbrakes	Thrust	Notes
1	S1-3.1	APU On								
2	S1-2.1	Engine Start	0 AGL			OPT	DN			
3	S1-1.1	Control Sweeps	0 AGL			OPT	DN			Elevator, Ailerons, Rudder, Spoilers
4	S2-1.1	Taxi	0 AGL			UP	DN			
5	S2-2.1	Takeoff	0 AGL			OPT	DN			
6	S2-3.1	Climb				UP	UP			
7	F15-8.3	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	UP	UP		Idle	
8	F15-8.4	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	UP	UP	Ext	Idle	
9	F15-8.5	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	1	UP		Idle	
10	F15-8.6	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	10	UP		Idle	
11	F15-8.7	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	25	UP		Idle	
12	F15-8.8	Stall Characteristics: Straight, Idle, -1kt/sec entry	10000-18000		1.3VSR	30	DN		Idle	

Figure 12 CG Management Table In Flight Package

In the CG Management section, the action of moving ballast is listed as "Before sequence #7" to get the aircraft to the desired configuration. Later down in the table, the trigger "When Gross Weight = 120000 lb" the ballast is moved again, to keep the GW/CG within the envelope. TOM provides the ability to specify these triggers in the flight sequence so that the test director always has the CG management actions available to them during the test. This improves the safety of the test by allowing the test planner to keep the GW/CG within the envelope, and improves the efficiency of the test by potentially allowing multiple configurations to be tested within the same flight, within reason.

3.5. Post-Test Status and Reporting

Upon completion of a test, the individual conditions performed may have varying statuses applied (Incomplete, Aborted/Not Executed, Unsatisfactory, Complete). The execution status of these conditions is important to maintain as test programs often require a certain number of successful executions per test point. TOM maintains the number of successful condition executions, allowing the flight planning FTE to have awareness on how many executions are still required for that condition. This improves the efficiency of the test program by not missing required executions. TOM also tracks data quality status. The quality of the data gathered during the test may be inadequate to meet the regulation or requirement even though the condition was performed correctly. This counts as an unsuccessful execution, and TOM will track that as well. This integration makes it easy when planning subsequent tests because icons are shown next to each condition, easily identifying if a condition still needs to be performed or not (Figure 13).

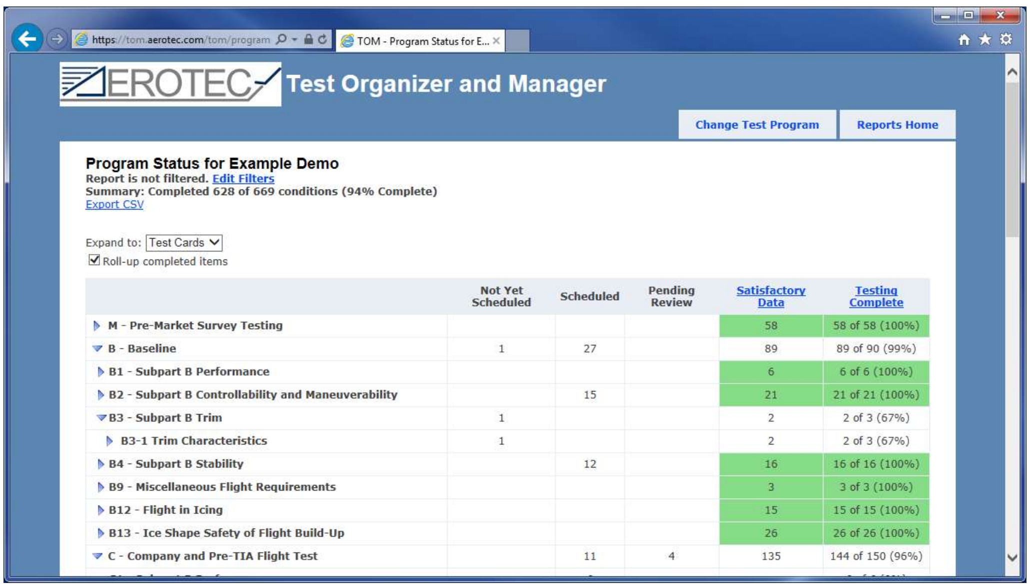


Figure 13 Test Condition Quality Tracking

With this information all integrated, TOM can also track the overall progress of the program and produce associated reports. These reports quickly show how many of the total conditions have been performed, how many have satisfactory data and how many of the remaining conditions are scheduled versus not yet scheduled then shows an overall program completion percentage based on conditions performed with satisfactory data. These reports can also be broken down all the way to the condition level to show exactly which conditions remain. If this integration did not exist, it would be extremely time consuming to check every single test to count conditions and then after that, check with the data analyst on whether the data captured was sufficient (Figure 14).

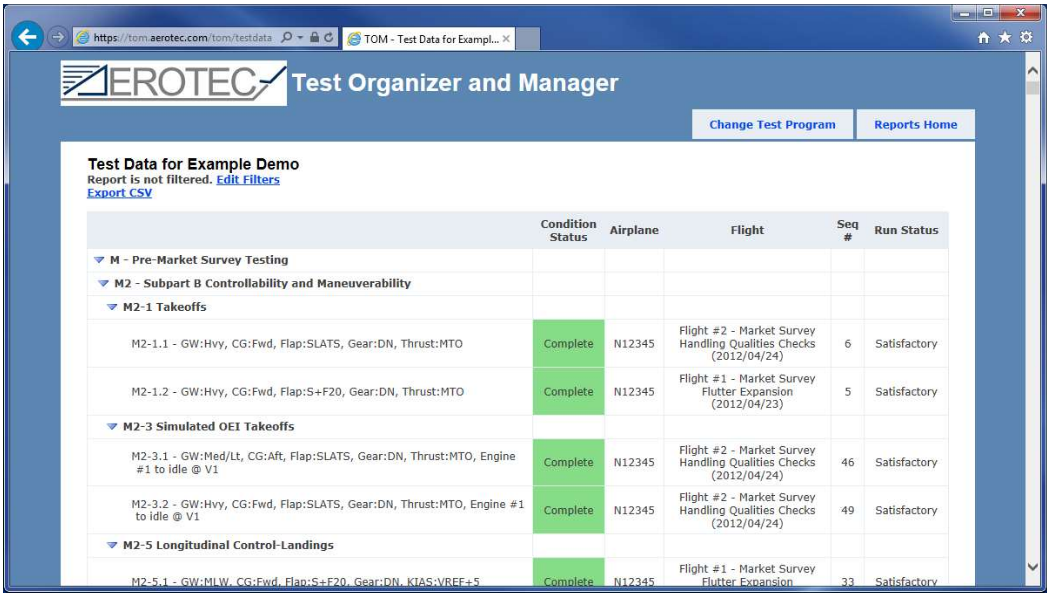


Figure 14 TOM Web Report

4. Conclusion

The importance of an integrated test planning approach is critical to the success and efficiency of any test program. A software platform that integrates all of the test planning aspects is the most effective way to perform this integration and also provides the efficiency and quality needed for a program to be successful and cost effective. TOM is an excellent example of an integrated test planning software platform that meets the needs of all test programs, big or small. TOM provides features useful to the entire test team, not just FTE's which saves the program time and money while at the same time improving the quality of all test artifacts.