



Executive summary

Multi-disciplinary installation of the Eagle's Eye

Problem area

NLR was tasked by the Dutch Ministry of Defense to answer the question, whether Unmanned Aerial Vehicles [UAV] can fly safely in European uncontrolled airspace without risking collision with other aircraft. The question was laid down in a National Technology Project, called 'OUTCAST' (Operations of (military) UAV – Transition to Civil Air Space and Traffic environments), which has been running within NLR since 2004. Phase 2 of OUTCAST consisted of 'Demonstrator Development' [Ref. 1] which was accomplished in 2007. The Dutch National Aerospace Laboratory [NLR] had designed a non-scarring construction for installation of a heavy camera in the nose of its research aircraft, a Cessna Citation 2. Aspects like structural strength, metal fatigue and air loads were considered in conformity with Federal Aviation Regulations [FAR] part 25. The European Aviation Safety Agency [EASA] Part-145 certified NLR Research

Aircraft Technical Operations [RATO] modified the aircraft. This paper describes the process of research, design, certification, fabrication and installation of the novel camera in NLR's research aircraft.

Description of work

Installation of the Toplite EO/ IR camera in the nose of the Cessna Citation II Research aircraft. All research required to set up the approved data was accomplished within NLR.

Results and conclusions

A complicated challenge was realized as a good result of cooperation between well experienced scientists and engineers, sharing thorough knowledge on various disciplines. This implied the research, design, development and certification of the Eagle's Eye installation in NLR's research aircraft Cessna Citation 2.

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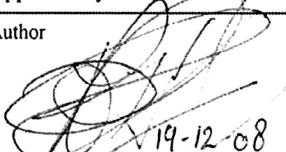
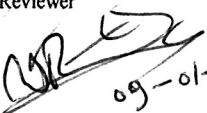

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Abstract

The Dutch National Aerospace Laboratory [NLR] had designed a non-scarring construction for installation of a heavy camera in the nose of its research aircraft, a Cessna Citation 2. Aspects like structural strength, metal fatigue and air loads were considered in conformity with Federal Aviation Regulations [FAR] part 25. The European Aviation Safety Agency [EASA] Part-145 certified NLR Research Aircraft Technical Operations [RATO] modified the aircraft. This paper describes the process of research, design, certification, fabrication and installation of the novel camera in NLR's research aircraft.

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List of Abbreviations

ACCL	(FAR 25) Article Compliance Check List
AOA	Angle of Attack
AOS	Angle of Sideslip
ATM	Air Traffic Management
CFD	Computational Fluid Dynamics
EASA	European Aviation Safety Agency
EO/ IR	Electrical Optical/ InfraRed
FAR	Federal Aviation Regulation
MAL	Mededeling aan Nederlandse luchtvaarders en eigenaren van vliegtuigen
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium
OUTCAST	(Operations of (military) UAV – Transition to Civil Air Space and Traffic environments
RATO	Research Aircraft Technical Operations
TCAS	Traffic alert and Collision Avoidance System
UAV	Unmanned Aerial Vehicles

List of Acronyms

EASA	European Aviation Safety Agency
FAR	Federal Aviation Regulation
MAL	Mededeling aan Nederlandse Luchtvaarders en eigenaren van vliegtuigen
OUTCAST	Operations of (military) UAV – Transition to Civil Air Space and Traffic environments
RATO	Research Aircraft Technical Operations

1 Prologue

NLR was tasked by the Dutch Ministry of Defense to answer the question, whether Unmanned Aerial Vehicles [UAV] can fly safely in European uncontrolled airspace without risking collision with other aircraft. The question was laid down in a National Technology Project, called ‘OUTCAST’ (Operations of (military) UAV – Transition to Civil Air Space and Traffic environments), which was running within NLR since 2004. Phase 2 of OUTCAST consisted of ‘Demonstrator Development’ [Ref. 1] which was accomplished in 2007.

2 Introduction

OUTCAST was based upon the ‘Detect and Avoid’ principle. Due to available time constraints, it was decided upon to use existing technology which easily fitted in current aviation infrastructure and ATM-procedures. For the demonstrator-development phase NLR had chosen to use its Cessna Citation equipped with the Traffic alert and Collision Avoidance System [TCAS], combined with an Electro-Optical/ InfraRed [EO/IR] camera. A ‘Toplite 3’ camera was chosen, weighing 60 kilograms. (132 lb), a diameter of 42 centimeters (16.5”) and a height of 60 centimeters (23.6”). Due to weight and dimensions of this camera, installation options were limited.

3 Deliverable

NLR RATO defined the deliverable as follows: ‘The end product as delivered is a certified and airworthy aircraft, being equipped with the specific EO/IR Camera, camera control systems and the UAV pilot ground station, which is located in the aircraft cabin for convenience.’



Fig. 1 Final and certified situation of camera installed on Cessna Citation 2

The following steps were defined to achieve the deliverable:

- Camera location options research and location option selection,
- Theoretical Aerodynamic research,
- Strength analysis and Structural design,
- FAR 25 Article Compliance Checklist,
- Approval of modification design,
- Approval, fabrication, assembling and installation of parts,
- Practical Aerodynamic validation,
- Certification of aircraft.

4 Camera location options and selection

As the camera to be used was fairly heavy, the camera installation location to be chosen was very important. The location options were limited. Camera position research had been focused on positions in the nose section, due to presence of structural provisions, to carry the heavy loads. Following positions had been researched:

- Fuselage hard points (which are located on Left Hand fuselage at cockpit/ cabin door position)
- Horizontal in the nose area
- Vertical upside down in the nose area
- Vertical upright in the nose area

Advantages (+) and disadvantages (-) of various positions

Ad 1) - On fuselage hard points:

- + Hard points were certified as a modification by Cessna Aircraft Company,
- + Hard points could carry heavy loads,
- + No removal of avionics required.
- With camera installed, limited ground clearance,
- Camera vision angle was not in conjunction with project requirements,
- Interface construction between hard point structure and camera required,
- Aerodynamic imbalance,
- Expected turbulent airflow into LH engine.

Ad 2) – Horizontal in nose area:

- + Aerodynamically, better than vertical.
- Due to camera design, the camera horizon does not match with actual aircraft horizon, expensive software upgrade required to correct this attitude difference,



- Camera vision angle was not in conjunction with project requirements,
- Compared to other options a more complex camera attachment structure required, because of camera Centre of Gravity laying forward,
- Avionics to be relocated and Weather radar to be removed, thereby providing space for the camera.

Ad 3) – vertical upside down in nose area:

- + Existing structure provisions can be used for installation,
- + Normal position of camera as being used in UAV's,
- + Good vision angle.
- Relocation of pitot-tubes required and consequently Position Error Correction flights to accomplish,
- Expected turbulent air flow over nose gear doors and into engine inlets during high Angle Of Attack [AOA] (i.e. take-off and landing),
- Airflow might be disturbed in side slip,
- Avionics to be relocated and Weather radar to be removed, thereby providing space for the camera.

Ad 4) – vertical upright in nose area:

- + Existing structure provisions can be used for installation,
- + No heavy additional modifications to be accomplished.
- Down vision-angle limited,
- Airflow might be disturbed in side slip and relatively high AOA,
- Avionics to be relocated and Weather radar to be removed, thereby providing space for the camera.

Position Choice

Based on presupposed cost analysis, expectations concerning structural strength and aerodynamic analysis, as well as the presence of existing structural provisions which could be used for camera installation, it was decided to install the camera vertically upright in the aircraft nose. Based upon this assumption, the design phase was executed.

5 Design

For setting up the design, NLR dealt with amongst others: matching FAR 25 [Ref. 2] articles, aerodynamical aspects, aircraft handling, safety factor, bearing factor, Continuing Airworthiness, and NLR's requirement to have a minimum of remaining structural changes on the aircraft after project accomplishment. To monitor the design process and time-path as planned, NLR had set up a FAR 25 Article Compliance Check List [ACCL]. This list contained all affected FAR 25 articles and the manner of showing compliance.

5.1 Basic principle for Design

1. camera position vertical upright in the nose area;
2. minimum aircraft scarring by this modification;
3. use of existing modification provisions;
4. equally diffused loads over the front airframe structure;
5. Acceptable aerodynamical impact;
6. design must be cost-effective;

Additional point of interest related to setup of the design: NLR's Cessna Citation has a national Certificate of Airworthiness (based on the use as a research aircraft). This fact, gave the opportunity to have the required research, design, classification, partial approval, manufacturing and installation accomplished within the NLR RATO.

With these basic principles (see 5.1) in mind the design phase was divided in: 'Theoretical Aerodynamical research' and 'Strength research'.

5.2 Theoretical Aerodynamical research

Theoretical Aerodynamical research (by use of the Computational Fluid Dynamics [CFD] method) was accomplished to investigate aerodynamic consequences of the modification; what was the effect on aircraft handling as well as airspeed and altitude indication?

The CFD research was accomplished on a simplified model of the modified Cessna Citation. The camera model was supposed to be round in circumference, whereas the camera itself has sharp edges. The flow around the Cessna Citation with camera, is modeled on the basis of the Reynolds averaged Navier-Stokes equations.

Aerodynamical points of attention

Large Scale flow separation: In the case large scale flow separation would occur, induced by the camera installation, this might increase adverse aircraft handling. Flow separation might increase vibration and buffeting, but it also might hamper precision maneuvers like cross-wind landings. Large scale flow separation might also shed vortices, transported downstream and decaying gradually, they still might exist at the tail plane area and the engine intakes in certain Angles Of Attack [AOA] (α) and Angle Of Sideslip [AOS] (β) combinations, these conditions could effect aircraft handling. A fairing was supposed to inhibit flow separation behind the camera and to avoid infra-red light from the camera hitting the pilot's eyes. The fairing would have positive influence; with fully attached flow over camera and fairing it would reduce the afore mentioned phenomena.

Destabilization Effect: Although the fairing might be effective, a destabilization effect in yaw remains, which could effect damping of the Dutch Roll. This might influence the maximum sideslip angle as well as the minimum control speed (V_{mc}). Thereby, forces on the vertical tail might be higher than a clean nose area.

Airspeed- and altitude indication disturbance: the flow disturbance over the forward fuselage area might disturb the indication of airspeed and altitude by disturbance of the static pressure at the location of the static ports.

Aircraft performance: the camera and fairing combination installed could cause increased pressure fluctuations by the flow traveling downstream the aircraft nose, resulting in an increment in boundary layer drag, which affected the aircraft (field) performance.

Questions to be answered by the CFD research

1. What was the effect on the boundary layer around the forward fuselage area after installation of the camera?
2. Was there an effect and – if yes - what was the effect of forces and moments on the aircraft after the installation of the camera?
3. What was the effect on the static air pressure around the static ports, i.e. would airspeed- and altitude indication be effected by the installation of the camera?

The following flight conditions had been researched by use of the CFD method, representing the critical conditions to be expected during flight:

(V = knots calibrated airspeed, α =AOA, β =AOS)

1. Stall ($V = 91$ kCAS, $\alpha = 12^\circ$, $\beta = 0^\circ$)
2. Cross-wind landing ($V = 118$ kCAS, $\alpha = 6^\circ$, $\beta = 16^\circ$)
3. High Speed flight ($V = 262$ kCAS, $\alpha = -0.3^\circ$, $\beta = 0^\circ$)
4. High Speed flight with sideslip ($V = 262$ kCAS, $\alpha = -0.4^\circ$, $\beta = 10^\circ$)
5. Dive ($V = 393$ kCAS, $\alpha = -0.8^\circ$, $\beta = 0^\circ$)

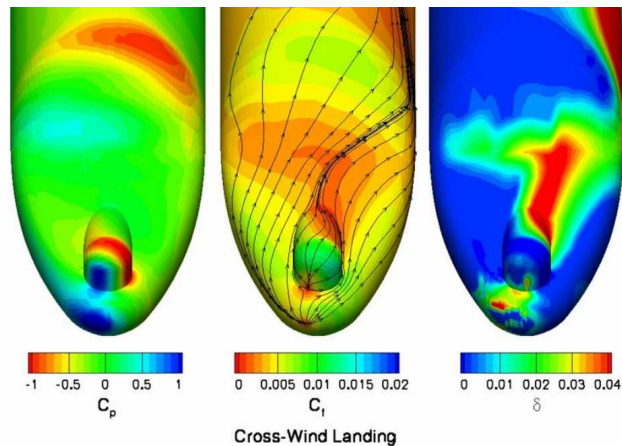


Fig. 2 Results of Surface Pressure Coefficient (C_p), Skin Friction Coefficient (C_f) and Boundary Layer Momentum-loss Thickness (δ) for the Cross Wind landing configuration.

Conclusion of CFD research

The CFD analysis revealed the following: it seemed possible to install the camera with fairing on the proposed position. The fairing should be able to avoid large scale flow separation downstream from the camera. Camera vibration will be reduced by use of the fairing. No indications were found concerning negative impact on aircraft handling quality or on airspeed- and altitude indication. Based on this conclusion, it was stated that camera and fairing installation for flight test execution is acceptable. Flight test execution is essential to verify in practice the CFD analysis.

5.3 Strength Analysis

The strength analysis was accomplished against the standards as laid down in:

- Aircraft Manufacturers report
- Federal Aviation Authority [FAA] regulations (FAR 25) [Ref. 2]
- Regulations from the Dutch Civil Aviation Authority [CAA-NL] (MAL 04/ 93) [Ref. 3]

For the design, attention was given to the following aspects:

1. camera load analysis
2. loads into the aircraft structure
3. camera attachment provisions
4. damage tolerance
5. bird impact

Design starting points

Starting point for the strength analysis was a Cessna Aircraft Company Report, which was set up by Cessna for the so called ‘fuselage-hard-point’ modification on NLR’s Cessna Citation

research aircraft. This report included an overview of all loads to be expected on an external store, mounted onto the fuselage hard points. The factors as mentioned in the Cessna report, for inertial and emergency loads were used in the strength analysis for the OUTCAST camera installation. Load factors for forward, backward and sideward loads as well as information regarding safety factor and bearing factor were found in reference [Ref. 2] and [Ref. 3], which gave information and instructions for installation of items in an aircraft.

As vibrations should absolutely negatively affect the whole project, special attention was paid to a non-vibrating construction. From this point of view a truss frame construction was chosen, with multiple support rod attachment points.

Mass of camera and attachment bracket was determined at 65 kg, which equaled 638 N. Air loads were determined at a pressure-coefficient $C_p = \frac{3}{4}$ for drag and vertical load, acting on the whole camera surface. For lateral loads, calculations were made assuming one camera side $C_p = +\frac{3}{4}$ and the other side assumed $C_p = -\frac{3}{4}$, which equaled a $\Delta C_p = 1.5$. Air loads were determined for an airspeed of 100 meter/ second. Ultimate load was safety factor (1.5) times limit load. The load calculations are summarized in Table 1 and Table 2:

Table 1 Overview of relevant loads

Situation	Load direction	Limit load	Ultimate load
Inertial	Gust down	+ 5,09 g	+ 7,635 g => 4874 N
	Gust up	- 3,09 g	- 4,635 g => 2959 N
	Drift landing	0,83 g	1,245 g => 795 N
Air loads	Drag	579 N	869 N
	Vertical	579 N	869 N
	Lateral	1158 N	1737 N
Emergency landing	Up		2 g => 1276 N
	Forward		9 g => 5740 N
	Lateral		1,5 g => 957 N
	Down		4,5 g => 2870 N

Table 2 Highest loads in the various directions

Directions	Manner of load	Calculated load
Down	Gust-vert. air load	4874-869=4005 N
Up	Gust+vert. air load	2959+869=3828N
Aft	Drag	869 N
Forward	Emergency landing	5740 N
Lateral	Air load	1737 N

The vertical air load was relatively low compared to inertial loads. It was assumed that the maximum Inertial Gust Down load was normative (4874 N).

As Drag load was small; therefore in longitudinal direction (forward and aft), the 9g situation was normative. In lateral direction the air load of 1737 N was normative.

Camera load analysis

Three load situations were calculated:

- Vertical gust load
- Load in longitudinal direction
- Load in lateral direction
- Vertical gust load (see Fig. 3)

Using the design dimensions and the vertical gust condition as shown in Table 1, being 4874 N, gave a load of 7052.2 N on tube DA. Because of the interconnection between the forward and aft brackets via the upper rods BC at an angle of 24°, the vertical load is calculated, being 11823 N, acting on forward and aft bracket. With this calculated load, the loads on BC and CF can be calculated. Calculations revealed loads as follows: on support rod BC 29068 N, on support rod CF 26555 N and on support rod BE 7662 N.

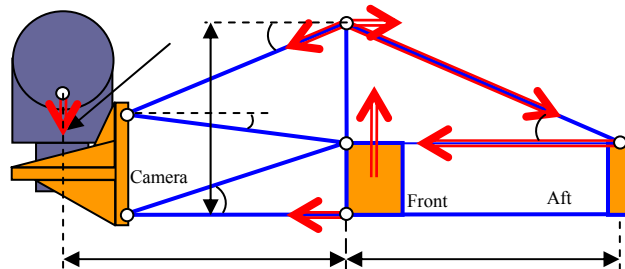


Fig. 3 Overview of load and forces

Load in longitudinal direction

In the 9g horizontal load situation, the dimension of the camera's Centre of Gravity with regard to the camera frame was important. The horizontal load was taken by the support rods EB and EF. Based on dimensions and an ultimate load of 10875, these rods were able to withstand the loads.

Load in lateral direction

Lateral loads occurred due to air loads, drift, and emergency landing conditions. The aerodynamical load of 1737 N ultimate was normative. The point of action of the dynamical lateral load is the heart of the camera-ball. At a distance of 336 mm (13,2") below the camera ball Centre of Gravity, a couple profiles was attached onto the camera bracket and onto the front



side of the nose wheel well over a width of 306 mm (12"). This couple profile was attached onto the nose wheel bay by use of ten rivets, and with two NAS bolts onto the camera bracket. This construction was able to withstand the shear load of 1737 N. Besides this couple-profile construction, it was assumed that the 'truss' frame would also absorb an uncertain amount of the lateral load.

Transferring Camera loads into the aircraft structure

To accommodate the relatively high loads into the airframe structure the inner side of the nose wheel bay was reinforced with doublers on the positions where the brackets were riveted. As the load on the front bracket was very high, a 'small doubler over a bigger doubler' construction was used. For riveting and attachments, existing rivet positions were used as well as some screw/ bolt positions; including rivet positions in stringers and girders. Thereby creating a shear-load-diffusing capacity. Because of the fairly thin standard nose wheel well structure of 0.6 mm (.02") thickness, Alclad 2024T3 doublers of 1.2 mm thickness (05") on each side on the inner side of the wheel well were riveted with MS 20470DD rivets, various diameters.

Camera attachment provisions

Using the information as distilled from the strength analysis like ultimate loads, a selection of materials to be used was derived; type of material, thickness of material, type and quantity of fasteners, etc. However, according to FAR 25 paragraph 25.623 each part that has free fit and that is subject to vibration must have a bearing factor (1.15), large enough to provide for the effects of normal relative motion.

With all this information the Design of Part for Research work could be set up for in total 46 different type of parts to be made within NLR and a parts list for standard hardware was set up (roughly one thousand standard parts were used). Survey of parts used: bolts NAS 1303, NAS 1133, NAS 1581, MS 21250, AN3, AN4, blind rivets CR3223, CR 3523, for sheet metal work Alclad 2024 T3, for parts to be machined Alclad 2024 T351, rod end type M81935/1-4, support rods Corrosion Resistant Steel ASTM-A-269, Ø 20x2.

Damage tolerance

What was the effect on the camera structure, if a high-loaded part in the structure should fail? As support rod BC was the critical part in this construction, it was therefore assumed that one of these support rods was no longer part of the construction in the damage tolerance situation. As the fuselage nose itself should take roughly 20% of the loads (because of the stiffness of the support rods frame compared to the upper-skin), the one installed support rod BC should take 80% of the load.

By use of two additional support rods to both sides of the nose baggage area, it was expected that the only problem might consist of brackets which cannot be expected to withstand the ultimate load of 18853 N. Before that should happen, it seemed to be clear that also the other support rod BC would fail. In that case the camera will partially hang onto the nose skin (6130 N), the installed brackets would however transmit a part of the load into the wheel well (1532 N). The whole construction was capable of carry these loads, and fulfilled thereby the requirements for damage tolerance.

Metal fatigue

This issue had been researched and was declared to be a minor item, because of the relatively small flight campaign, the ‘over- dimensioned’ frame assembly and a monitoring tool for continuing airworthiness. As vibration was a fatigue originator, NLR had chosen for the use of a ‘vibration-minimizing’ truss frame construction.

Bird impact

For the construction to be ‘bird-impact-proof’ the fairing was modified, based upon the following assumptions and information:

- Camera was a cylinder, so the point of impact can be assumed to be a small flat surface,
- Camera Centre of Gravity was most dangerous point of impact (at 100 mm (3,9”) below centre line of camera ball),
- If bird didn’t hit camera centre line, bird would bounce off,
- Size of bird 1.8 kilograms (4 pounds),
- Greatest moment on point of impact,
- Average bird impact force, F_{av} : 45 kN,
- Maximum bird impact force, F_{max} : 90 kN.

Although calculations were made, the experience from Bird Impact tests showed that it was hard to have a solid basic understanding of how a structure would behave during bird impact.

Conclusion from calculations in case of average bird hit, was that bolts MS 21250-05 with tensile strength of 1250 N/mm² will fulfill the structural requirements of camera attachment onto camera bracket. The support rods onto the camera bracket lugs would be attached with NAS 1581 bolts, which had a tensile strength of 1100 N/mm², these bolts would also fulfill the structural requirements. Conclusion for average bird impact force: load in 9 g horizontal condition was comparable but slightly lower than bird impact with F_{av} . The structure will withstand F_{av} .

In the F_{max} situation the bolts should not withstand the load. Therefore an additional provision was made; a reinforcement thick aluminum plate was riveted onto the base plate of the fairing. This provision should absorb roughly 20% of the peak load and would import this as shear load

onto the nose skin. This implied that 80% of the peak load must be absorbed by the camera support structure. In the F_{\max} situation it was assumed that the support rods might be butted and it was expected that prior the camera might touch the fairing, most of the energy was already absorbed by the whole construction. It was therefore concluded that in the F_{\max} situation, the construction would possibly deform.

5.4 Structural design

Camera mounting

The camera was mounted on an aluminum bracket. The loads introduced by the camera were transmitted from the camera installation bracket to a tube frame, which was installed symmetrically on both sides of the nose gear wheel bay. Via the tube frame the loads would be transmitted to (in total four) brackets which were riveted onto both vertical sides of the nose gear wheel bay structure. The camera bracket itself was hanging, by use of in total 8 tubes, which were attached onto the camera bracket and the forward nose wheel bay bracket (see). For accommodating the camera in the aircraft nose area, a 410 mm (16.15") diameter hole was made in the upper side of a new nose and radome assembly.

Fairing

A single direction curved plate strengthened with ribs, strips along edges, L-profiles and a base plate, was installed behind the camera.

The front fairing side was nearly closing onto the camera, the aft side was mounted onto the nose area skin. The distance between camera and fairing was 5 mm (.20"). The area between camera and nose area was filled up using an aluminum ring-plate which encloses a rubber preformed seal. The air loads on the fairing were calculated at 970 N ultimate load in vertical gust condition, whereas the lateral load resulted in 1385 N ultimate load. Based upon these loads it was calculated that the use of twelve fasteners of type NAS 1133 were enough to withstand the air loads.

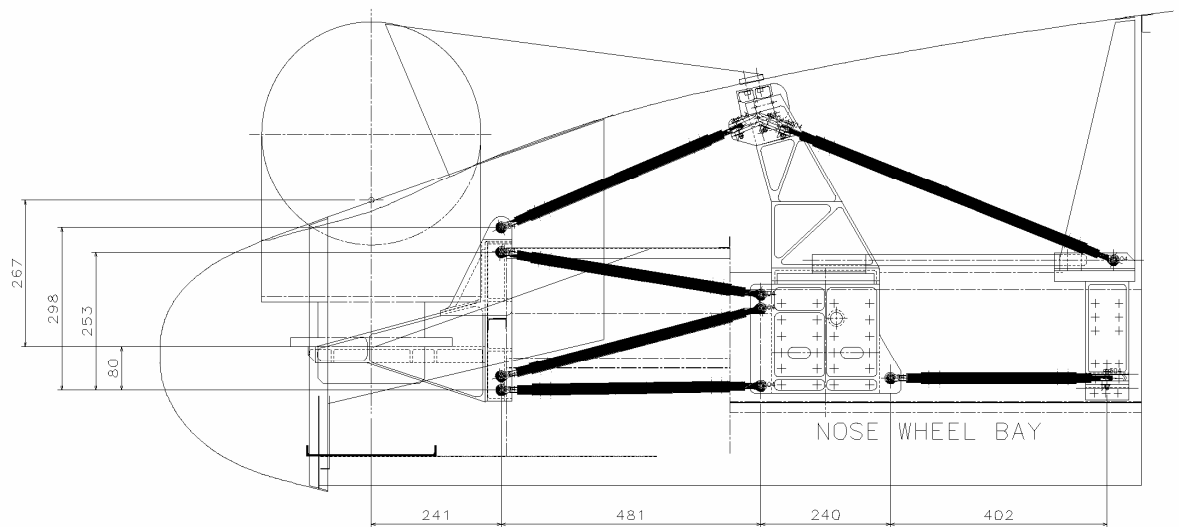


Fig. 4 Drawing of the brackets and frame construction

Lightning protection and Bonding

As the nose of an aircraft was susceptible to a lightning strike, it was important to pay attention to this item. The camera manufacturer had specified that the camera mounting surface was treated as being a bonding platform. The camera bracket was prepared with bonding capacity on the camera contact surface and had a profile onto the front side of the nose gear bulkhead. Additionally for lightning protection and bonding, all support rods were provided with ‘grounding cables’ which were attached to the aircraft structure. Besides these provisions, the new aircraft nose itself was equipped with the discharge strips and the fairing itself was attached to the structure by use of bolts.

End situation after camera removal

After execution of the OUTCAST flight program, all items riveted onto the aircraft like doublers, filler plates and brackets stayed in the aircraft, being subject to periodical inspections. All non-riveted hardware was removed from the aircraft. The end situation resulted in a 4 kg’s higher Empty Weight of the aircraft.

6 FAR 25 Article Compliance Check List

For a good and smooth certification process, regular meetings with CAA-NL were organized and a FAR 25 ACCL was set up. This list contained items as mentioned in FAR 25 paragraphs, affected by camera installation, on various disciplines, being: Flight, Structure, Design and Construction, Powerplant, Equipment and Operating Limitations/ Information. The FAR 25



ACCL listed the FAR 25 Subpart as affected by the modification, the specific FAR 25 paragraph number, short description of FAR 25 paragraph, relation with the modification, manner of showing compliance and the responsible person within the organization. A total of more than fifty paragraphs were covered.

The FAR 25 ACCL served as a monitoring tool for planning purposes and a communication status report for the contacts with the various departments within NLR as well as with CAA-NL. NLR has derived much benefit of the FAR 25 ACCL as being a compliance checklist for the whole certification process.

Table 3 Example of 2 items on FAR 25 ACCL

Sub-part	Pararaph	Description	Relation	Compliance
Flight	25.149	Minimum control speed V_{mc}	Camera in front of C of G increases V_{mc}	Aerodynamical analysis
structure	25.303	Factors of safety	Design criteria for brackets + structure interface	Design and analysis

7 Approval of modification design

NLR's RATO had procedures in its Maintenance Organization Exposition [MOE] to handle modifications on the aircraft. These procedures were classified as NON-Part 145 procedures. To handle design requests for Aircraft Modification or Parts for Research work, NLR possessed of five Approved Inspectors on a total of four different disciplines. The four disciplines covered by the Approved Inspectors were: Structures, Avionics, Flight Characteristics and Cabin Safety. The approved inspectors were authorized to classify a design and if classification was stated as 'minor-minor' he was authorized to approve a design. For the Eagle's Eye installation, a total of four different Designs of Aircraft Modifications [DAM] were supplied to the Approved Inspectors:

- DAM 06-004: relocation of two gyros, the communication and navigation receivers,
- DAM 06-005: OUTCAST camera installation,
- DAM 06-007: moving backwards of avionics trays,
- DAM 06-008: DME 2 relocation.

Based upon regulations and criteria as mentioned in the MOE, all DAM's except DAM 06-005 were classified as 'minor-minor'; whereby internal approval process was the solution to get the so-called Maintenance Data. However, the design for the OUTCAST Camera installation was

classified as 'Major'; based upon: Aerodynamical aspects, Weight and Balance impact and the in-depth calculations to be made. Major classification implies certification process to be accomplished by Aviation Authorities, either national or European. NLR's Citation was an Annex 2 aircraft, thereby having an ICAO based National Certificate of Airworthiness, which provided the opportunity to have this DAM handled by the CAA-NL. CAA-NL handled the certification process as a national Supplemental Type Certificate [STC]. Upon showing compliance to all articles on the FAR 25 ACCL, CAA-NL issued a national STC (SA 0601 NL).

8 Approval, fabrication, assembling and installation of parts

The parts required for the modification consisted of standard hardware like rivets, bolts, nuts, cotter pins, etc. as well as own Designed Parts for Research work. These parts being designed internally within NLR were handled in a comparable classification and approval process as the DAM's. After the designs were approved by the Approved Inspectors, a total of 46 different types of parts were made by NLR's sub-contracted machining workshop. After certification of the fabricated parts, all parts were prepared and if required, assembled together. A total of roughly one thousand parts standard hardware was used for the modification. All parts for research work were assembled and installed in the aircraft in accordance with accompanying approved drawings, all in accordance with NLR RATO's MOE.

9 Practical Aerodynamic validation

This phase was meant to show compliance with the FAR 25 ACCL, accomplished by taxi and flight tests.

9.1 Taxi Tests

To verify the conclusions of the theoretical CFD research, high speed (with nose up 8°) taxi tests were accomplished with tufts stuck onto the nose and cockpit area of the aircraft. After assuring by use of video monitoring, that no large scale flow separation occurred, the flight test program started.

9.2 Flight Tests

The flight test program focused on: controllability, maneuverability, directional and lateral control, minimum control speed V_{mc} , stability, static-lateral-directional-stability, dynamic



stability, vibrations and buffeting, maneuver and gust conditions, yawing conditions, airspeed and altitude indications. The flights were conducted prior the modification with the clean aircraft, and after the modification. Tufts were stuck on the nose and cockpit area. In flight the following equipment was used: video monitoring system, Global Positioning System, Inertia Reference System, Flight Control Position Synchro's. An additional Air Data Computer was used for recording time, position, airspeed, altitude.

The first flight revealed a loud sound when camera itself was pitched up; this was solved by installation of a fairing below the lens area, thereby closing the gap. The second flight revealed a big sound when the camera turned around. This problem was solved by making fairing spoilers around the circumference of the camera, being attached onto the nose and the fairing, furthermore the fairing was filled up with a two-component expanded polyurethane. These actions having accomplished, revealed NLR's Research Aircraft, the Cessna Citation as behaving very well in flight!

10 Continuing Airworthiness

For showing compliance for continuing airworthiness, NLR had set up an inspection program consisting of an initial inspection to be accomplished after first flight, a pre-flight inspection to be accomplished before every first flight of the day. Then in follow up range a more in-depth inspection with increasing flight hours (in this case a flight hour defined as an hour with camera installed). In addition to these inspections, an inspection was included in the Supplemental Inspection List of the remaining modified construction and must be accomplished every 150 aircraft flight hours.

11 Certification of Aircraft

In order to hand over an airworthy and certified aircraft, it was required to have all processes (regarding the complete modification including part manufacturing), being followed in relation with the specific requirements, all as laid down in the MOE. Two key-words in these processes were traceability and identification. Those were covered within NLR RATO, EASA Part 145 approved organization

Important milestone in the certification process was the release of the national STC SA 0601 NL by the CAA-NL. This STC release was based upon accomplishment of all actions mentioned in the FAR 25 ACCL. All actions being accomplished by the NLR RATO were written on a NLR RATO Work Order, with references to the approved data. After each item



being accomplished, each Work Report was signed off by approved NLR RATO Certifying Staff. By sign off of all matching work reports, Certifying Staff was able to Release the Aircraft to Service and hand over the modified airworthy aircraft to the NLR Research Aircraft Flight Operations.

12 Conclusion

A complicated challenge was realized as a good result of cooperation between well experienced scientists and engineers, sharing thorough knowledge on various disciplines. This implied the research, design, development and certification of the Eagle's Eye installation in NLR's research aircraft Cessna Citation 2.

13 References

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