Initial flight testing of the F-104CCV, still serialled 33+91 before it became 98+36, was undertaken without the canard, the fairings for the CCV actuators were the most obvious modifications at this stage.

AT THE END OF THE 1970s, the introduction of the Panavia Tornado into Luftwaffe service was imminent. Since it had been designed as a fighter-bomber, the F-104G Starfighter and F-4F Phantom II would have to soldier on in the air-to-air role, but — following the typical development cycles for fighter aircraft — the then big German aerospace companies, MBB, VFW-Fokker and Dornier, had started studies for their successor at the beginning of the decade. This work was self-funded and aimed to put a new fighter into service in the 1990s. It was dubbed the Taktisches Kampfflugzeug der 90er Jahre (TKF90).

Lessons learned from the past and studies investigating future air-to-air tactics called for the ability to aim the gun independently of the aircraft's velocity vector, as well as flying at high angles of attack and achieving high turn rates over a large speed range up to Mach 1.8. Combined with improved agility was the requirement for low trim drag, but this could only be achieved with an unstable aircraft configuration.

The advantage of such a fighter was very tempting: the increased lift and reduced drag would lead to longer range or render possible weight reductions of around 10–15 per cent. This would also cut the cost of the future aircraft. But a price had to be paid, as this configuration had to be examined only vaguely before, and little knowledge about flying in this envelope was available. Many people even doubted that it could be made work.

Only by these means could the full potential of this new concept be exploited, but an aircraft in this configuration could not be handled manually by a pilot. The pilot's control inputs had to be given to a computer, which would calculate the deflections of the control surfaces and thereby enable the aircraft to be flown safely. Knowledge of flight control software had been acquired by MBB during testing of the vertical take-off V101 jet, however, know-how regarding the controllability of such unstable aircraft, the so-called Control Configured Vehicle (CCV) technology, remained sparse.

The F-104 was not the ideal aircraft for such an undertaking, but it came at zero cost.

NILS MEISTER

The F-104CCV in its definitive external configuration, with the additional Starfighter elevator atop the fuselage. (Aviation Images/Andrew Chastney, via author)

The F-104 was not the ideal aircraft for such an undertaking, but it came at zero cost. BIRTH OF CCV

In 1974 the German MoD (Bundesministerium für Verteidigung, BMVg) authorised MBB within the framework of the Komponenten Experimentalprogramm Luft (KEL, or component experimental programme, air) to conduct a CCV demonstrator programme on the basis of an F-104G Starfighter. Its aim was to test this new technology and, in the words of the project description, "to develop an appropriate redundant flight control system and test the flight characteristics of a highly unstable supersonic jet fighter equipped with such a control system over the whole flight envelope". Furthermore it mentioned explicitly that "proof of increased performance by CCV is not within the framework of this programme.

Nils Meister, the former project pilot of the F-104CCV, remembers these times very well. He explains that the aim was to replicate the Starfighter's mechanical steering by electrical means, "the bottom line was to 'actively re-fly' the F-104", as Meister puts it.

An early test flight from Manching with the canard fitted.
In parallel to the CCV, MBB continued in TKF90 studies and presented the outcome on 26 April 1978. It was a delta-canard concept, with the canard foreplanes positioned far forward, as was intended in the single F-104G. This was close to the final configuration of the future Eurofighter Typhoon demonstrating the CCV programme's success.

The CCV team, meanwhile, gradually approached the final configuration of the modified Starfighter that was needed to split the ambitious project into two phases. Phase 1 would cover the definition and development of the CCV flight control system and the testing of the sensors in flight. This helped define the parameters for the control algorithms during flight tests. One example involved the pre-defined deflection of the elevator and measuring the resulting reaction. This had to be done thoroughly, because even though the F-104 had already been in German service for years, these figures were so unknown that no documentation existed.

Thirteen flights were necessary to obtain this data, comprised between 27 September and 4 November 1976.

Phase 1 was much more extensive — the testing of the flight properties of an increasingly unstable aircraft. Modifications to the F-104G. Most obvious was the arrangement of the canard foreplanes, the rudders, and which included dihedral to ensure the maneuverability of the CCV and its stability at high speeds. There was no room to house these actuators inside the slim and sleek F-104. The control mechanisms therefore had to be hidden under quite prominent bulges attached to the fuselage. Originally it was planned to fit them near the ailerons, but it did not prove possible to obtain certification for the necessary wing modifications. Though very eye-catching, these bulges, according to Nils Meister, did not influence the flight characteristics. At most there were some very slight vibrations or minimal flow separation.

On the subject of finding a CCV platform, Nils Meister continues: "The F-104 was... for sure, not the ideal aircraft for such an undertaking, but it came at zero cost to the company, as it was provided by the BWTA (the Bundesamt für Wehrtechnik und Beschaffung, the Federal Office for Military Technology and Procurement). It was available, it was cheap, and it was practical."

The Starfighter's flight controls were well-adjusted, as Meister states, steering and control were always proportional to the movement, whatever at 200kt or at Mach 2.0 — all done mechanically and without fancy electronics! This was an ideal pre-condition for replacement with an electronic control unit. Of course the F-4 Phantom it would have been an alternative, but it never offered much space for the new equipment, but, Meister adds, it was "way too big, and heavy..."

**BECOMING UNSTABLE**

The second test phase began at the end of 1976 and lasted for more than four years. It included numerous ground and flight tests, and saw the aircraft flying in two versions for basis (basic) and for Time (dusk, or more appropriately, cannon). In all, five specific configurations were involved:

- **B1:** Standard F-104G with CCV flight control software
- **B2:** With 600kg of aft and 160kg of front ballast
- **B3:** With canard wing and 220kg of nose ballast
- **E1:** With 400kg of aft ballast
- **E2:** With 600kg of aft ballast

The approach is obvious enough: a highly stable platform was turned into an unstable one by shifting the aircraft's neutral point and center of gravity. All this was done as slowly and cautiously as possible, Meister recalls. Tests of the different configurations were carried out in the simulator — there they even did some aerobatics, within the bounds of the Starfighter's capabilities and the CCV controls.

The most obvious alteration to the F-104CCV followed in the middle of 1976: adoption of configuration E1, turning the fuselage-mounted canard, an additional Starfighter elevator situated just behind the cockpit. This was the next step toward creating a truly unstable aircraft, by moving the neutral point further forward. It was also listened to test reactions to control surface input similar to those planned for the future TKF90.

A first flight in this configuration was completed on 19 November 1980. It turned out that the aircraft was still somewhat stable, as the aft ballast had been removed and replaced with 250kg of ballast between the cockpit and the rear seats. From then until January of the following year, the aircraft was flown, primarily flown. According to the test pilots, the aircraft was stable, as long as there is not too much momentum loaded on the aircraft. At 200kt a 400kg addition was added to the aft weight compartment, as had been done previously, and the center of gravity shifted back. Flight tests in the unstable configuration now began. The period between July and September 1981 was very intense, with 26 flights. The results achieved made the CCV team so confident that the trim weight in the nose was removed and 200kg added to the aft compartment. Now, once again, there was 600kg of lead shot mounted at the corresponding approximately 10 per cent of the empty weight of a regular Starfighter. The initial flight in this E3 config was on 1 December 1981, and the equipped, controlled flight at 20 per cent negative longitudinal stability was achieved — a great breakthrough and a great flight test at the testing, Nils Meister told Classic Aircraft. It was generally very uncompromising, but this is what you try to achieve in flight testing, exploring new areas as much as possible and as safely as possible.

The aircraft flew so well that 'every 104 pilot could have climbed in and flown it. The 104 was still a 104'.

Even so, the CCV programme's 176 flights brought results that were later incorporated into the Rockwell-MBB X-31 test program and it also left its mark on today's Eurofighter Typhoon.