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D E C I S I O N
of 23 June 1997

Case Number: T 0210/95 - 3.5.1

Application Number: 84302734.3

Publication Number: 0148550

IPC: G05D 1/08

Language of the proceedings: EN

Title of invention:
Method and apparatus for thruster transient control

Patentee:
SPACE SYSTEMS / LORAL INC.

Opponent:
Deutsche Aerospace Aktiengesellschaft

Headword:
Spacecraft control/FORD AEROSPACE

Relevant legal provisions:
EPC Art. 52(1), 56

Keyword:
"Inventive step - yes"

Decisions cited:
-

Catchword:
-

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Case Number: T 0210/95 - 3.5.1

D E C I S I O N
of the Technical Board of Appeal 3.5.1
of 23 June 1997

Appellant: (Opponent)
Deutsche Aerospace
Aktiengesellschaft
Patente
Willy-Messerschmitt-Strasse, Tor 1
D-85521 (DE)

Representative:
-

Respondent: (Proprietor of the patent)
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Representative:
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Decision under appeal:
Interlocutory decision of the Opposition Division of the European Patent Office posted 29 December 1994 concerning maintenance of the European patent No. 0 148 550 in amended form.

Composition of the Board:

Chairman: P. K. J. van den Berg
Members: R. Randes
G. Davies

Summary of Facts and Submissions

I. European patent No. 0 148 550 was granted on 20 June 1990 on the basis of European application No. 84 302 734.3, filed on 24 April 1984 and claiming priority from 21 April 1983.

II. The appellants (opponents) filed an opposition against the European patent on 20 March 1991 on the ground that the subject-matter of the claims lacked an inventive step (Article 100(a) and 56 EPC) in the light of the state of the art disclosed in the document

X1 = EP-A-0 046 151.

III. In the proceedings before the opposition division, the appellants maintained their request that the patent be revoked, even after the respondents (proprietors of the patent in suit) had filed a new set of claims in the oral proceedings before the opposition division, held on 25 November 1994. Claim 1 of said request reads as follows:

"A method for use in a spacecraft (10) to counteract disturbance transients during a change in velocity manoeuvre, the spacecraft (10) employing a plurality of thrusters (18,20,22,24,26,28), at least a first thruster and a second thruster (e.g. 18,20) being disposed to develop mutually counteractive moment arms to thrust relative to at least one axis (e.g. roll) through a centre of mass of the spacecraft (10), said first thruster (e.g. 18) and said second thruster (e.g. 20) being capable of developing unequal moment arms of force, the method comprising the steps of:

- storing prior to said manoeuvre a value representative of an estimated actual disturbance torque (e.g. at 134),

F:6 thereafter, throughout said manoeuvre modulating in response to said stored value (e.g., from 134) one of said first and second thrusters (e.g., 18, 20),

F:7 by applying a prebias command to a summer (e.g., 96) which in turn controls a modulator (e.g., 102) of said one of said thrusters (e.g., 18, 20) during said manoeuvre to counteract an actual disturbance torque a sufficient amount to compensate for said estimated actual disturbance torque in order to minimize a net position error (e.g., Φ),

F:8 without reference to said net position error (e.g., Φ),

F:9 detecting said net position error (e.g., Φ), said net position error (e.g., Φ) being indicative of a difference between said estimated actual disturbance torque and said actual disturbance torque with respect to said axis (e.g., roll),

F:10 and generating a loop control command for said modulator (e.g. 102) of one of said thrusters (e.g., 18, 20),

F:11 said loop control command and said prebias command being substantially independent of each other

F:12 and separately applied to said summer (e.g., 96),

F:13 thereafter modulating one of said thrusters (e.g., 18, 20),

F:14 in response to a sum of said prebias command and said loop control command during said manoeuvre

F:15 to counteract said actual disturbance torque to further minimize said net position error (e.g., Φ).

The characterizing features (F) have been numbered as done by the opposition division in the said decision.

The set of claims, moreover, included dependent claims 2, 3 and 10 appended to claim 1 and additionally an independent apparatus claim 4 corresponding to the method claim 1 and dependent claims 5 to 9 appended to the independent claim 4.

IV. By an interlocutory decision within the meaning of Article 106(3) EPC, delivered orally at the end of said oral proceedings and posted on 29 December 1994, the opposition division maintained the patent in amended form on the basis of the set of claims filed during said oral proceedings.

V. The appellants lodged an appeal on 8 March 1995, paying the appeal fee on the same day. The statement of grounds of appeal was filed on 8 May 1995. The appellants maintained their request to revoke the patent for reasons of lack of inventive step.

The appellants, having regard to X1, expressed the opinion that the function of the features F6 to F12 of claim 1 were in principle disclosed by the teaching of said document. Having regard to the device of Figure 6 of X1, it appeared that a separate and independent

prebias command was applied to a summer Σ_4, which corresponded to the summer related to in feature F7 of claim 1. This was because according to X1 a value corresponding to an estimated disturbance torque was delivered to an integrator 1/s (at the left of said Figure 6) to be preset. The integrator, however, was connected to said summer Σ_4 only over an amplifier (K_Z), while the rest of the loop, i.e. the normal "loop control", between the said integrator and said summer Σ_4 was connected over different integrating branches. Thus, the signal from the integrator directly input (with amplification K_Z) to summer Σ_4 could be regarded to be the said independent "prebias command" according to claim 1. Moreover, the appellants were of the opinion that the filter device 303 introduced between the summer Σ_4 and an additional summer Σ_5 according to the text of X1 was not compulsory. It also appeared that said filter, appropriately designed, would not delay the signal from the summer Σ_4 to the summer Σ_5.

In the statement of appeal the appellants also cited a new reference, a handbook,

D2 = "Regelungstechnik" by Otto Föllinger, Elitera-Verlag, Berlin 1978, pages 20, 21 and 27 to 31.

The appellants expressed the opinion that said document("Bild 1/22" and the corresponding text) taught that a set value was superimposed onto the output of an integrator and remained unchanged as long as it was fed to its input. Thus, the set value and the integral, in principle, remained independent of each other.

VI. In a letter, filed on 18 January 1996, the respondents contested the argumentation of the appellants and expressed the opinion that their invention clearly involved an inventive step. Therefore, they requested that the appeal be dismissed. Moreover, they requested

that "the costs which have been incurred by the owner of the patent due to late submissions of the book O. Föllinger 'Regelungstechnik' be imposed on the opponent".

The respondents, having regard to the teaching of X1, in summary put forward the following arguments.

Document X1 explained the development of the suggested devices according to Figures 5 to 8 of X1. Figure 2b of said document disclosed a classical concept of a control device. According to said prior art the spacecraft was detected by a detector ("Lagesensor"), generating a detector signal which was fed to a control unit, which unit in turn generated a further control signal which was input to summer Σ_5, directly connected to the PWPF modulator, controlling the spacecraft.

X1 referred to a new concept for a control unit based on the "Beobachtertheorie". This new concept used a detector KS (cf. Figure 3 of X1), the output signal of which was fed into a control unit which in turn was connected to summer Σ_5 which controlled the PWPF modulator. According to this new concept the components of the "Beobachter" and a "Regler" together formed the control unit corresponding to the classical control unit according to Figure 2b.

However, as had been disclosed by X1 (page 14, second paragraph) neither the concepts disclosed in 2b, nor the ones disclosed in Figure 3 were apt for a position control of elastic spacecrafts due to the problems involved in **structural elasticity**. This was the reason why the output signals of the control unit were input to an additional summer Σ_4 before the summer Σ_5 and an additional filter device 303 had to be inserted between the summers Σ_4 and Σ_5 (Figure 6 of X1), which device

comprised at least two further filters of first order or one filter of at least second order for generating the correct signal to summer Σ_5 the output of which was controlling the said modulator.

Moreover, according to the arrangement of Figure 6 of X1 the starting conditions of integrator 1/s for generating a desired output were estimated and an estimated value was set. The respondents pointed out that "by disclosing amendment of the starting conditions of an integrator, document X1 disclosed **intervening into** the control unit by setting the starting conditions of the integrator".

According to the present invention the detector signal generated by the earth sensor 36 was coupled to the roll error detector 108, which generated a pre-bias command directly to summer Σ_{96}, corresponding to the summer Σ_5 of X1. Therefore, the inventive concept according to the present patent established an additional path bypassing the entire conventional control unit for adding said prebias command to summer Σ_{96} which controlled the modulator PWPF 102. Thus the present invention, contrary to X1, **avoided intervening** with the control unit by establishing a bypass.

In relation to the prior art the invention achieved the following advantages:

(a) The normal feed back control loop had only to deal with a relatively small unexpected disturbance torque and, therefore, needed only a relatively low gain. On the contrary, the circuits of X1 had to operate correctly on the maximum torques occurring during manoeuvre and needed a high gain.

(b) According to the invention the transition from stationary conditions to change of velocity manoeuvre did not create any problems due to the fact that the unequal torque was immediately and essentially compensated by said estimated disturbance torque.

According to X1 an integrator had to be reset which meant that the output value of it was going from the preceding output value to exactly the reset value. This meant that the information present in the control loop from the stationary conditions before the start of the change in velocity manoeuvre was completely lost due to the fact that the outputs of integrators were forced to a set of equilibrium values from preceding manoeuvres which could not consider the stationary conditions of the control loop immediately before the starting of the current change in velocity manoeuvre. Thus, the resetting of the integrator fully destroyed the information on the stationary state before the start of the manoeuvre.

(c) The prebias command, dealing with the estimated disturbance torque due to a change in velocity manoeuvre, was, according to the present invention, switched on and off together with the manoeuvre control command without disturbing the operation of the normal control loop. Thus, also, at the end of the change in a velocity manoeuvre the transition to the state after the manoeuvre was as smooth as the beginning of the transition of change of velocity.

(d) The prebias command according to the invention was not generated within the feedback loop. Therefore, no delay between the manoeuvre control command and the prebias command could occur. In contrast

thereto, the system of document X1 had an inherent delay of the control loop which, therefore, also delayed the command derived from the value of the integrator set at the start of a change of a velocity manoeuvre.

With regard to advantage (b) the respondents contested the interpretation of the teaching of document D2 given by the appellants. They pointed out that the appellants in their argumentation had not taken into account that the teaching of said document (concerning "Bild 1/22", page 21), in fact, started from the condition that all time-dependent functions were equal to zero for $T \leq 0$ (cf. page 21, left hand side column in the middle "Ganz generell sei angemerkt...") which meant that at the time the integrator was set with an initial value, the value generated by the integrator before was considered to be zero. This, however, meant that at the time the integrator was set with an initial value, the integrator would forget the value generated before.

VII. In a communication, dated 3 July 1996, the Board expressed the preliminary opinion that the arguments in favour of the present invention put forward by the respondents in the letter, filed on 18 January 1996, were convincing. However, since the appellants had not filed any reply to those convincing arguments, the Board stated that "it would be appropriate to get the appellant's view on said arguments in writing and/or a message whether oral proceedings are still requested". The Board also expressed the provisional opinion that it could see no reason why the costs incurred by the respondents by the late submission of the said book D2 would be imposed on the opponents. Said reference

appeared to represent average knowledge in the technical field concerned and was aimed at interpreting the relevant document X1, since there had been different opinions upon said interpretation in the proceedings before the opposition division.

VIII. In a letter, filed on 15 March 1997, the appellants stated that they withdrew their request for oral proceedings and requested that a decision be taken according to the state of the file.

IX. Thus, the appellants request that the decision be set aside and the patent be revoked in its entirety.

The respondents request that

the appeal be dismissed, ie that the patent be maintained in the amended version according to the interlocutory decision of the opposition division, and that

the costs which have been incurred by the respondents due to late submission of document D2 be imposed on the opponent.

Reasons for the Decision

1. The appeal is admissible.

2. Having regard to the prior art disclosed in X1 and the subject-matter of claim 1 (and the subject-matter of the corresponding apparatus claim 4) of the present patent, it appears to the Board that the objective problem to be solved could be seen in improving the control system of the spacecraft in such a way that the manoeuvres could be made smoother and faster.

The respondents have argued that said problem is solved by the features F6 to F15 of claim 1. As has been mentioned above (see under VII above), the Board stated in the communication, dated 3 July 1996, that said argumentation was convincing. In this respect the Board notes that the appellants have not contested said argumentation, although the Board expressly invited them to do so. Therefore, the Board does not see any reasons why it should change its opinion.

Thus, according to the invention, in addition to a normal control loop for a spacecraft as disclosed in X1, an additional path bypassing the entire normal control loop for adding a prebias command directly to summer Σ_{96} (corresponding to summer Σ_5 in X1) has been established. This means that the normal control loop has to deal only with a normally small unexpected disturbance torque. It is clear, as has been pointed out by the respondents, that the arrangement of Figure 6 of X1 has deliberately been designed with further filters 303 to meet the requirements of structural elasticity. It, therefore, appears that a skilled person trying to improve the controlling of elastic spacecrafts in an obvious way would not refrain from using such filters. Those filters, however, contribute to a delay of the signal from the reset integrator 1/s which signal according to the appellants should be compared with the said prebias command according to the invention and which does not introduce such a delay in the control circuit proper. In that respect, the Board also shares the opinion of the respondents that, when setting the starting conditions for integrator 1/s, information present in the control loop of X1 from the stationary conditions before the manoeuvre is completely lost (see last paragraph of VI above).

In summary, the Board considers that the invention - by adding the prebias signal to the loop control signal and applying the sum directly to the modulator - solves the objective problem posed and achieves the following effects as already suggested by the opposition division:

- since the "compensating" prebias signal does not pass through further circuits, the signals within the loop remain small and its parameters can be dimensioned independently of the high gain necessary in the prior art arrangement of X1,

- the prebias signal is allowed to be distributed throughout a manoeuvre, resulting in a reduced peak level of disturbance,

- the control loop is kept operating (closed) with out being reset before a manoeuvre by setting the initial values of the integrators,

The Board, therefore, is of the opinion that the subject matter of method claim 1 and the subject-matter of the corresponding apparatus claim 4 are not obvious to a skilled person. The patent, therefore, meets the requirements of Articles 52(1) and 56 EPC.

3. Consequently, the appeal has to be dismissed.

4. With regard to the respondents' request that the "costs which have been incurred by the respondents due to late submission of document D2 be imposed on the opponent", the Board takes the view as expressed and explained in the said communication, dated 3 July 1996 (and not contested by the respondents), that said request should be refused (cf under VII above).

Order

For these reasons it is decided that:

1. The appeal is dismissed.

2. The request that the costs which have been incurred by the respondents due to late submission of document D2 be imposed on the opponent is refused.

The Registrar: The Chairman:

M. Kiehl P. K. J. van den Berg