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Assessment of a Supervisory Fault-Hiding Scheme in a Classical Guidance, Navigation and Control Setup: the e.Deorbit mission

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Abstract— **The design of a model-based Fault Tolerant Control (FTC) strategy based on Virtual Actuators (VA) in a built-in Guidance, Navigation and Control (GNC) setup is addressed for the e.Deorbit space mission. This mission, initiated by the European Space Agency (ESA), aims at removing a large defunct satellite from Earth orbit: ENVISAT. The goal of this paper is to promote academic solutions to add fault tolerance capacities against thruster faults without any change or new tuning of the already in-place GNC solution. The validation of the proposed FTC solution is assessed by a simulation campaign based on a high-fidelity nonlinear industrial simulator.**

I. Introduction

A. Motivations

According to [1], the number of orbital debris at the Low Earth Orbit (LEO) becomes critical. With the decreased costs to reach the space in the new programs, the debris population could inevitably grow and could lead to a rise of impractical orbital regions for space activities. In this context, the European Space Agency (ESA) has initiated a mission, entitled e.Deorbit, to remove a large (8.2tons, 26m × 10m × 5m) ESA-owned satellite from the LEO protected zone: ENVISAT. This motivated ESA to manage different debris removal solutions. One of them is based on a robotic arm, see Fig. 1. To this end, a joint academic and industrial research project named COMRADE (COntrol and Management of Robotics Active DEbris removal) has been initiated two years ago [2, 3]. The COMRADE study is limited to the development of solutions to the so-called Capture, Stabilization and Rigidisation phases of ENVISAT. Since these phases are crucial ones for the success of the mission, some on-board abilities in terms of fault detection, isolation (FDI) and tolerant control (FTC) are required for the thruster-based chaser actuation system. This facet fitted with the fact that studies demonstrate that thruster faults account for approximatively one quarter of all Attitude and Orbit Control System (AOCS) failures [4], underlines a need of efficient FDI and FTC solutions to the mission fulfillment. The work addressed here should be understood in this context, *i.e.* it is mainly an application of the known academic theory applied to an industrial issue.

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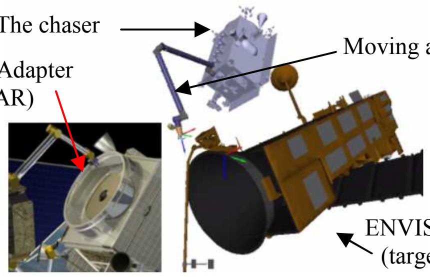

Figure 1. The ESA's e.Deorbit mission

B. Antecedents and paper contribution

In the literature, there exist a lot of academic papers dealing with the design of FTC solutions for spacecraft. Here, it is proposed to only focus on solutions used in real space missions. It appears that very few papers have been published to tackle the FTC problem dedicated to thruster faults. The main reason comes probably from to the historically use of hardware redundancy that leads to the development of reliable GNC setup with over-actuated feature [5, 6, 7].

Dealing with FTC solutions, Control Allocation (CA) solutions (see [8] for a survey) scheduled by a FDI unit, is the most retained. For instance, the work in [9] addresses the development of a CA-based FTC solution for flexible satellites. In [10, 11], the classical SIMPLEX-based CA algorithm is changed by the Nonlinear Inverse Pseudo Control (NIPC) solution to improve the FTC performances of the terminal rendezvous phase of the Mars Sample Return mission. An alternative solution can also be found in [12, 13] by acting at the guidance level. The FTC strategy consists of the following principle: if the chaser is outside the so-called approach corridor or/and with an attitude outside of a pre-defined threshold, then a switch on a healthy redundant thruster set is made and a "retreat" maneuver is engaged. A new rendezvous trajectory is then planned by the guidance algorithm.

If it is possible to find some papers addressing the FTC problem for space debris removal missions [14, 15], it must be outlined that the only solution that has been assessed on an industrial high-fidelity benchmark considering the full problem (model of the avionics and actuators, propellant sloshing, non-spherical gravity acceleration, gravity gradient, solar radiation pressure, third-body perturbation (Moon and Sun), Earth magnetic disturbance and aerodynamic drag) is the one proposed in [16]. In the work of [16], the FDI solution dedicated to the studied space mission is based on a new class of nonlinear unknown input observer. Fault tolerance is next achieved by means of the CA-based NIPC technique that is updated by FDI signals.

This paper aims at proposing an alternative solution to the NIPC-based FTC technique. The FDI unit is the one given in [16] and we propose to maintain the initial SIMPLEX-based CA algorithm. The fault tolerance will be thus achieved in a fault-hiding paradigm setup [17]. The motivation of using this technique as opposed to other existing ones, comes from the fact that the already in-place control loops (and especially their structure) that have been designed by the industrial partners of the project, are kept as they are, achieving *de facto*, the required robust performance when no fault occurs in the chaser's propulsion unit. The fault tolerance is obtained by inserting a reconfiguration block between the baseline control unit and the plant, see [18-21] to have some examples. The FTC principle consists of a reconfiguration unit – known under the name of Virtual Actuators (VA) – that hides the presence of a fault from the already in place controller. Of course, this reconfiguration unit is only if a fault has been occurred and declared by the FDI unit.

The aim of this paper is thus to present the development and assessment of a VA-based FTC solution against thruster faults that may occur in the chaser spacecraft during rendezvous with ENVISAT. Note that the assessment is performed on the same high-fidelity nonlinear industrial benchmark used in [16] that is assumed to be fully representative of the mission. It is developed in Matlab/Simulink, within the library called SPACELAB that contains e.g. sensors, actuators, dynamic, kinematic, environment models and a universe library that provides the ephemerides of Earth, Moon, and Sun.

II. PROBLEM STATEMENT

In this study case[1]., the considered reference scenario focus on the first part of the ENVISAT capture phase, *i.e.* the synchronization one. This phase starts with a transition from Parking Hold Point to Capture Point during which, the chaser synchronizes its motion with the target's movements until a position close enough so that the robotic arm can be deployed to capture ENVISAT at the grasping point located on the Launch Adapter Ring (LAR), see Fig. 1. As already mentioned, the FTC solution consists in introducing VA units that will be in charge to hide the faults to the already in-place control law, see Fig. 2 for an illustration. Following the fault hiding paradigm [18-21], it is required a model of "what is seen from the VA unit" for its design. This is the purpose of the following sub-sections. Note that the derivation of this model is guided by the objective of designing the FTC scheme. In this sense, it is a simplified version of what has been implemented in the industrial benchmark.

A. *Modelling the chaser dynamics*

The chaser's model consists of its translational and rotational dynamics, considering all forces and torques acting on it. These dynamics are derived from the Cowell method (orbit dynamics and kinematic), the second Newton's law (rotational velocity) and the kinematic equations of the attitude parametrization, *i.e.* Euler (3,2,1) angles. Forces and torques that are considered are those caused by propellant sloshing, the propulsion system (24 thrusters equip the chaser) and disturbances. Propellant sloshing in tanks (two tanks equip the chaser) is modelled as a linear 3D spring-mass model that considers the Coriolis, the centrifugal, the Euler accelerations, the disturbances and of course, the forces and moments due to the actuation unit. The considered disturbances are central body acceleration, non-spherical gravity acceleration, gravity gradient, solar radiation pressure, third-body perturbation (Moon and Sun), the Earth magnetic field and the aerodynamic drag. Merging all these models into a unique state space, leads to a nonlinear state space representation that admits as inputs, forces $F_s(t)$ and torques $T_s(t)$ generated by the propulsion units and the above listed disturbances that we gather in a vector denoted $d(t)$. In terms of outputs, denoted $y(t)$, we consider the relative position and velocity, the chaser's angular rate and attitude. Then, considering that the relative velocity and the angular velocity are relatively small (which is the case for short range rendezvous mission), the nonlinear model can be approximated using a first order Taylor approximation. This leads to a linear state space representation of order 48 (12 for the rigid body + 36 dedicated to multiplicative uncertainties), with $u = [F_s^T \quad T_s^T]^T$, the disturbances d and outputs y.

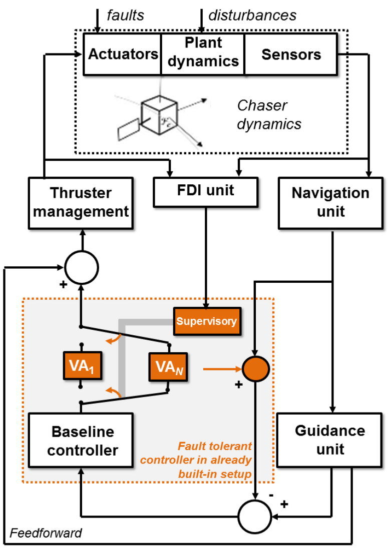

Figure 2. The proposed fault tolerant GNC setup

[1] Due to confidentiality reasons, we only discuss on the modeling principles, without any numerical values or deep details. The interested reader can however refer to [22] to more information.

The so-derived model obviously depends on some uncertainties that mainly consist of the mass of the chaser, the propellant masses, and the modes of propellant sloshing (both in terms of frequencies and damping factors). To carry out these uncertainties, the Linear Fractional Transformation (LFT) formalism [23] commonly used in the H_∞/μ control community, is used. This boils down to the following model of the chaser dynamics

$$P:\begin{cases}\dot{x}=A_1x+B_1\left(\eta^T \quad d^T\right)^T+B_2u\\ \varepsilon=C_1x+D_{11}\left(\eta^T \quad d^T\right)^T+D_{12}u\\ y=C_2x+D_{21}\left(\eta^T \quad d^T\right)^T+D_{22}u\end{cases} \qquad (1)$$

where $x\in\Re^{48\times1}$, $y\in\Re^{12\times1}$, $u\in\Re^{6\times1}$ and $d\in\Re^{6\times1}$. η and ε are internal signals linked with $\eta=\Delta\varepsilon$ and the uncertainty block Δ is defined according to

$$\Delta=diag(\delta_m I_3,\delta_{s1d}I_9,\delta_{s1f1}I_9,\delta_{s1f2}I_9,\delta_{s1f3}I_9,\delta_{m1}I_3,\\ \delta_{s2d}I_9,\delta_{s2f1}I_9,\delta_{s2f2}I_9,\delta_{s2f3}I_9,\delta_{m2}I_3):\delta_k\in\Re,\|\Delta\|_\infty\le1$$

where $\delta_m,\delta_{mi},\delta_{sid}$, $\delta_{sifj}, i=\overline{1,2}\ j=\overline{1,3}$ refer to the mass uncertainty, the propellant masses, the damping factors and the frequencies of the sloshing modes, respectively.

B. The baseline controller

The chaser controller obeys to a feed-forward/feedback structure that issues force and torque commands to track the reference trajectories delivered by the guidance unit. The feed-forward is managed at the guidance level that is described later, in section II.F. The feedback controller has been designed using the H_∞ mixed sensitivity approach [24]. This boils down to a linear controller robust against the uncertainties Δ. Its state-space representation is given by

$$\begin{cases}\dot{x}_c=A_cx_c+B_c(y_{ref}-y)\\ u_c=C_cx_c+D_c(y_{ref}-y)\end{cases} \qquad (2)$$

where $y_{ref}\in\Re^{12\times1}$ and $x_c\in\Re^{102\times1}$ are the reference signal to track and the controller state vector, respectively. A_c,B_c,C_c and D_c are real matrices of appropriate dimensions.

C. The thruster management unit

The thruster management unit is nothing else than a control allocation algorithm used to convert the force and torque commands $u_c(t)$ (see Eq. (2)), into thruster commands $u_{THR}(t)$. In this study case, the engineers proposed to retain the SIMPLEX-based algorithm [8]. Note that the spacecraft possesses 24 thrusters of $22N$ to control both attitude and position motions. Let us introduce the thruster configuration matrix $\mathrm{M}_{\mathrm{THR}}\in\Re^{6\times24}$. The elements of $\mathrm{M}_{\mathrm{THR}}$ are the influence coefficients defining how each thruster affect each component of u in (1), *i.e.*

$$\mathrm{M}_{\mathrm{THR}}u_{THR}=u_c \qquad (3)$$

According to [12, 16], a useful model of the thruster management unit has been considered here. It consists of the left pseudo-inverse of $\mathrm{M}_{\mathrm{THR}}$ so that $\mathrm{M}_{\mathrm{THR}}{}^{+}u_c=u_{THR}$, where $(\bullet)^+$ denotes the left pseudo-inverse of matrices.

D. The FDI unit

The FDI unit is based on the technique described in [16] that consists of a new class of NonLinear Unknown Input Observers (NL-UIO) that is optimal in the L_2-gain sense. The interested reader can refer to [16] to have a clear overview of this solution, from the fault isolability discussion to the NL-UIO design.

E. The navigation unit

It is important to recall that for this space mission, ENVISAT (the target) will be considered like a passive target, *i.e.*, the ENVISAT's actuators, sensors and its telemetry system cannot be used. Hence, the retained avionic architecture for the chaser is composed of a Light Detection and Ranging (LIDAR) unit which allows having the full relative pose estimation, an Inertial Measurement Unit (IMU), 3 Star Tracker heads, a Sun Sensor, a Global Positioning System (GPS) receiver and a GPS constellation propagation. Based on these sensors, the navigation algorithm is modelled using performance models [29] of the current situation of the chaser both relative to the target, (relative position and velocity) and its attitude and angular velocity. We recall that these last measures are those associated with the model (1).

F. The guidance unit

The feed-forward actions and trajectory reference profile mainly consist of a classic rendezvous trajectory (forced translation while keeping a constant relative attitude) and a spin synchronization trajectory, see Fig. 3 for an illustration.

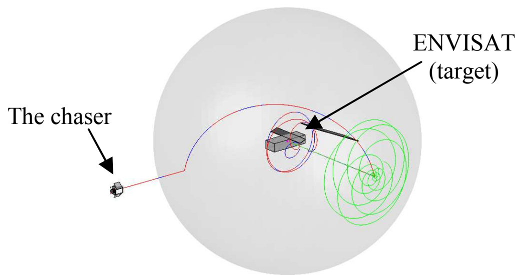

Figure 3. The synchronisation trajectory

G. Problem formulation

We are now ready to formulate the FTC design problem. Fig. 4 shows in details how the proposed FTC solution operates at the GNC level. The goal we pursue is to design the virtual actuator units, to cover any type of fault occurring in the thrusters. Following the method proposed in [18-21], we need to design a total of 25 VA units, one (the first, $i=1$) is devoted to the fault-free case and the others ($i=\overline{2,25}$) are dedicated to faults that may occur in the 24 thrusters. The control signal applied to the plant will be now $u_{f_i}, i=\overline{1,25}$ (defined later) instead of u_c. According to [18-21], all VA units can be designed under the assumption of

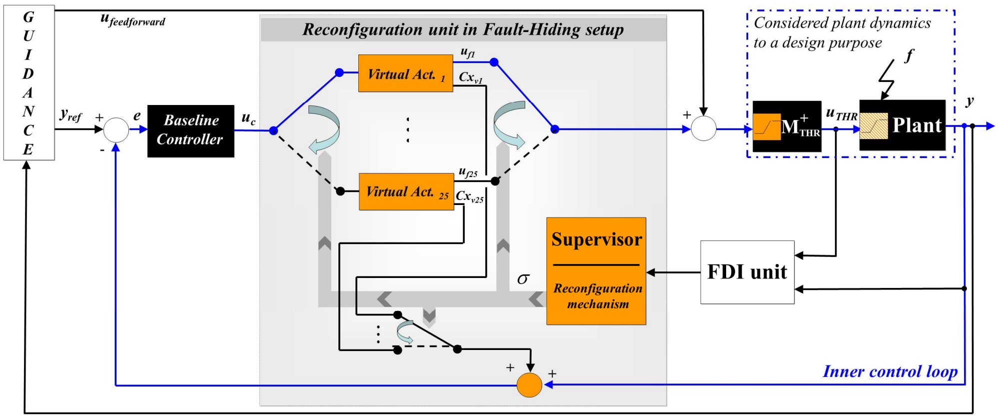

Figure 4. Fonctional diagram to formulate the FTC design problem

no uncertainty. Indeed, the baseline controller will be able to manage correctly the uncertainties when the fault hiding paradigm succeeds. Finally, and as it is extensively discussed in [18-21], the fundamental problem of the control signal saturation that may occur due to the presence of a fault, can be managed in this setup belonging to the fault-hiding paradigm. To taking into account all the previous aspects, the model (1) is reformulated for the i^{th} operating mode according to:

$$\begin{cases} \dot{x} = Ax + B_i sat(u_{f_i}) \\ y = Cx \end{cases}, \quad B_i = BW_i \mathrm{M}_{\mathrm{THR}} \qquad (4)$$

where $W_i = diag(w_{ki}), k = \overline{1,24}$ is a diagonal matrix so that the fault-free situation corresponds to $W_i = I_{24\times24}$ If the k^{th} element w_{ki} is equal to 0, this means that the k^{th} actuator is out of order. The function $sat(u_{f_i})$ is defined according to:

$$sat(u_{f_i}) = \begin{pmatrix} sat(u_{f_i1}) \\ \vdots \\ sat(u_{f_i6}) \end{pmatrix}, sat(u_{f_i1}) = \begin{cases} \alpha_{i1} & (u_{f_i1} > \alpha_{i1}) \\ u_{f_i1} & (|u_{f_i1}| \le \alpha_{i1}) \\ -\alpha_{i1} & (u_{f_i1} < -\alpha_{i1}) \end{cases} \qquad (5)$$

From (4) and Fig. 4, it can be seen that it is proposed to relocate the physical input saturations in input constraints on the desired forces and torques. This is why the saturation function of Fig. 4 is now put on the input signal of the thruster management unit. With this setup, the signal u_c of (3) is now replaced by the fault tolerant control signal $u_{f_i} \in \Re^{6\times1}$, $i = \overline{1,25}$. This signal is provided by the i^{th} VA unit (see Fig. 4) that has been designed to the i^{th} mode, from a bank of pre-computed VAs defined according to

$$\begin{cases} \dot{x}_{v_i} = (A + B_i^* M_i)x_{v_i} + (B_1 - B_i^*)u_c \\ u_{f_i} = N_i u_c - N_i M_i x_{v_i} \end{cases}, \quad i = \overline{1,25} \qquad (6)$$

where $M_i \in \Re^{6\times12}$ are the virtual actuator gains to be designed such that $(A + B_i^* M_i)$ is Hurwitz. The matrices N_i and B_i^* are obtained by:

$$N_i = (B_i^*)^+ B_1 \qquad (7)$$

$$B_i^* = B_i N_i = B_i (B_i^*)^+ B_1 \qquad (8)$$

Following the notations introduced previously for the model (4), B_1 is the fault-free matrix of (4), *i.e.* $B_1 = B\mathrm{M}_{\mathrm{THR}}$. From Fig. 4, it can be noticed that the output of fault tolerance unit is given by $y + Cx_{v_k}$ where x_{v_k} corresponds to the state of the selected virtual actuator.

Remark 1: In fault-free situation, the first VA is inserting in the closed-loop. This situation doesn't degrade the control performances achieved by the baseline controller since $(B - B_1^*)$ is equal to zero. By choosing $x_{v_1}(0) = 0$ and since $(A + B_1^* M_1)$ is Hurwitz, we directly applied the control signal u_c to the plant. This setup has been proposed to have a setup able to deal with the case of *intermittent* fault.

Once a fault has been diagnosed by the FDI algorithm [16], a switching mechanism is engaged to select the adequate VA unit. Here, the switching algorithm that is proposed is based on the supervisor concept [21], [26], [27]. In this approach, the switching logic is a decision map that generates a piecewise constant switching signal $\sigma(t)$. The problem can thus be formulated according to:

Problem 1: Let the baseline controller (2), the model (4) that covers the 25 operating modes with the associated VA unit given by (6)-(8) be considered. Let the following control law be introduced

$$u = \begin{cases} u_{f_1} & t < t_s \\ u_{f_i} & t \ge t_s \end{cases}, \quad i = \overline{1,25}$$

where t_s is the fault occurrence time declared by the FDI module described in section II.D. The goal we pursue is to design u_{f_i} $i = \overline{1,25}$ subjected to input constraints (5) by means of the i^{th} virtual actuator (6) and the model (4) such that $(A + B_i^* M_i)$ is Hurwitz. □

III. Solution to the Problem

Before starting the FTC design, it is natural to ask about the ability of the spacecraft to fulfill its mission in spite of a thruster fault. To answer this question, a preliminary study based on [28] can be performed. The following can be considered if and only if the faulty situation is recoverable. A solution to Problem 1 is given by the following theorem.

Theorem 1: For each operating mode $i=\overline{1,Q}$ with Q=25, let the following design problem be considered Q times to obtain Q virtual actuator gains. Let ${X_{va_i}}^{-1}$, P_i and Γ_i be defined such that

$$He\left\{\begin{pmatrix} v_{f_i} A_{cl} P_i^{-1} & 0 \\ v_{f_i} A_i^* P_i^{-1} & A{X_{va_i}}^{-1} + B_i^* \Gamma_i \end{pmatrix}\right\} \prec 0 \tag{9}$$

$$\begin{pmatrix} {X_{va_i}}^{-1} & \left(\Gamma_i^{(j)}\right)^T \\ \Gamma_i^{(j)} & \dfrac{\left(\dfrac{\alpha_{ik}}{\left\|N_i^{(k)}\right\|} - \mu_{f_i}\right)^2}{n_{\tilde{u}_i}} \end{pmatrix} \succ 0 \quad k=\overline{1,6} \quad \left\|N_i^{(k)}\right\| \neq 0 \tag{10}$$

hold where:

$$A_{cl} = \begin{bmatrix} A - B_1 D_c C & B_1 C_c \\ -B_c C & A_c \end{bmatrix} \tag{11}$$

$$A_i^* = \left(-(B_1 - B_i^*) D_c C \quad (B_1 - B_i^*) C_c\right) \tag{12}$$

$$\mu_{f_i} = \max_{e(P_i, v_{f_i})} \left\|u_c\right\| \tag{13}$$

${N_i}^{(k)}$ is the k^{th} row of N_i. In the same spirit, $\Gamma_i^{(j)}$ denotes the j^{th} row of Γ_i. $v_{f_i} \in \left]0,1\right]$. $n_{\tilde{u}_i}$ is the number of non-zero elements in ${N_i}^{(k)}$ and j in (10) takes values corresponding to the indices of the non-zero elements in ${N_i}^{(k)}$. $He\{M\}$ is equal to $M+M^T$. Then, the virtual actuator gain M_i obtained by $M_i = \Gamma_i X_{va_i}$ will guarantee that the plant (4) controlled by (2) and (6) is contractively invariant and respect the input constraints given in (5). ■

Proof: The proof of Theorem 1 is mainly based on the one developed in [19]. Here, it is just shown that the solution is still valid even if the baseline controller contains integrators (which is the case for (2)) and when the state vector dimension of the controller (2) and the plant (4) differ (which is often the case when a controller is designed using a H_∞/μ synthesis technique). To proceed, let the control loop composed by (2), (3), (4) and (6) be considered without including (5). When the operating mode is well identified, the closed-loop can be put in a block-triangular form by introducing the variable $x_{w_i} = x_r + x_{v_i}$. It follows that the state-space representation can be written according to

$$\begin{pmatrix} \dot{x}_{cl_i} \\ \dot{x}_{v_i} \end{pmatrix} = \begin{pmatrix} A_{cl} & 0 \\ A_i^* & A + B_i^* M_i \end{pmatrix} \begin{pmatrix} x_{cl_i} \\ x_{v_i} \end{pmatrix} + \begin{pmatrix} B^y \\ (B_1 - B_i^*) D_c \end{pmatrix} y_{ref} \tag{14}$$

where:

$$x_{cl_i} = \begin{pmatrix} x_{w_i} \\ x_c \end{pmatrix}, \; B^y = \begin{pmatrix} B_1 D_c \\ B_c \end{pmatrix} \tag{15}$$

Assuming that $y_{ref} \in L_\infty^{y_{ref}}$ is exogenous and bounded, the stability of the closed-loop involves the stability of:

$$\begin{pmatrix} \dot{x}_{cl_i} \\ \dot{x}_{v_i} \end{pmatrix} = \begin{pmatrix} A_{cl} & 0 \\ A_i^* & A + B_i^* M_i \end{pmatrix} \begin{pmatrix} x_{cl_i} \\ x_{v_i} \end{pmatrix} \tag{16}$$

Let the following Lyapunov function be considered

$$V_{2_i}(t) = \begin{pmatrix} x_{cl_i}(t) \\ x_{v_i}(t) \end{pmatrix}^T \begin{pmatrix} \frac{P_i}{v_{f_i}} & 0 \\ 0 & X_{va_i} \end{pmatrix} \begin{pmatrix} x_{cl_i}(t) \\ x_{v_i}(t) \end{pmatrix} \tag{17}$$

where X_{va_i} is a symmetric positive definite matrix. To guarantee $\dot{V}_{2_i} < 0$, it is necessary to verify

$$He\left\{\begin{pmatrix} \frac{P_i}{v_{f_i}} & 0 \\ 0 & X_{va_i} \end{pmatrix} \begin{pmatrix} A_{cl} & 0 \\ A_i^* & A + B_i^* M_i \end{pmatrix}\right\} < 0 \tag{18}$$

that is a Linear Matrix Inequality (LMI) equivalent to (9) by introducing $\Gamma_i = M_i {X_{va_i}}^{-1}$. Hence, the closed-loop is asymptotically stable by taking into account (9) in a LMI problem. Now, let the discharge on input constraints be now removed to complete the proof. Following the procedure introduced in [19], it is possible to show the validity of theorem 1. Since the procedure is similar to [19], the remaining of the proof is not explicitly given here. The interested reader can refer to [19] for more details. □

Theorem 1 provides the conditions to design the gain of virtual actuators in order to maintain the closed-loop system state inside a stable region as long as this state belongs to this region at the fault isolation time t_s.

IV. NONLINEAR SIMULATION CAMPAIGN

Independently of the FTC solution, it is fundamental to guarantee that the available actuator resources are sufficient to maintain the control objectives despite the presence of a thruster fault. This is refers to the fault compensability property. This problem is formulated in [28] using the so-called attainable force/torque domains. Applying this technique to our problem, the result revealed that it is possible to fulfill the e.Deorbit capture mission in the case where one thruster is out of order. Two other key features in the theory presented in section III can be extracted:

- the determination of the parameters $\alpha_{ik}, k=\overline{1,6}$ for all $i=\overline{1,25}$ involved in (5) that fundamentally represent the maximum attainable force/moment in the x, y, z directions, under fault-free and faulty situations. This problem has been solved using the attainable force/torque domains analysis technique;
- the determination of the parameters μ_{f_i} $i=\overline{1,25}$ that enter in (10) and represent the maximum magnitude of u_c according to (13). These parameters have been determined through several simulations in healthy situations.

The VA units are implemented within the industrial high-fidelity simulator of the e.Deorbit. Figures 5 and 6 show the obtained results when the thruster 1 is stuck in open position. The same simulation has been performed when the already in-place GNC setup works in healthy (green line) and faulty (dotted red line) situations, and when the proposed solution has been integrated (blue line). If the improvement for the relative position error is mainly related to the time necessary to recover the nominal (no fault) situation (see Fig. 6), one can noticed an improvement of 45% on the transient attitude errors after the fault occurrence, see Fig. 5.

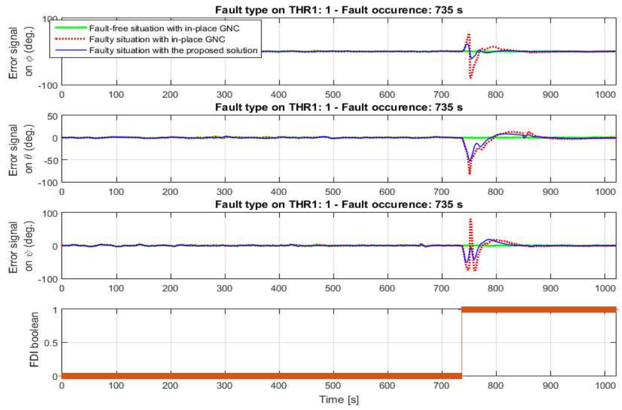

Figure 5. Attitude errors for a fault in the thruster 1

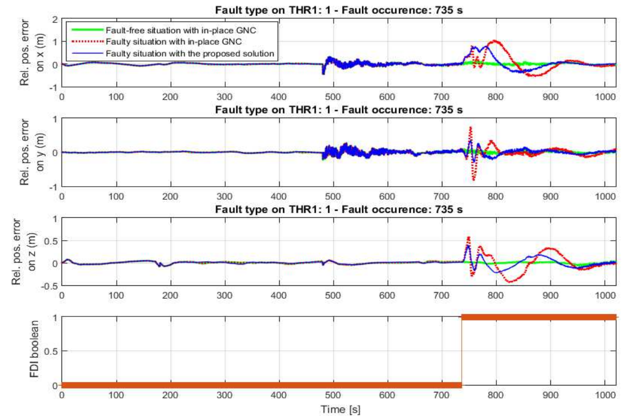

Figure 6. Relative position errors for a fault in the thruster 1

V. CONCLUSION

In this paper, a model-based FTC strategy against thruster faults has been presented for the ESA's e.Deorbit mission whose aim it to remove the satellite ENVISAT from the Earth orbit. It is shown that the proposed FTC scheme can be integrated in an already built-in GNC setup and tuned to achieve specific objectives in nominal (no fault) situations. A simulation campaign based on a high-fidelity industrial benchmark will be made in future works to appreciate the efficiency of the proposed solution. Another improvement will be relative to the assessment of this technique for a less actuated system to better appreciate its benefit.

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