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# Guidance and Control for High Dynamic Rotating Artillery Rockets

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**The acceleration autopilot with a rate loop is the most commonly implemented autopilot, which has been extensively applied to high-performance missiles. Nevertheless, for spinning rockets, the design of the guidance and control modules is a challenging task because the rapid spinning of the body creates a heavy coupling between the normal and lateral rocket dynamics. Nonlinear modeling of the rocket dynamics, control design as well as guidance algorithms are performed in this paper. Moreover, discrete-time guidance and control algorithms for the terminal phase, which is based on proportional navigation, are performed. Finally, complete nonlinear simulations based on realistic scenarios are developed to demonstrate the robustness of the proposed solution with respect to uncertainty regarding launch, environment and rocket conditions. The performance of the proposed navigation, guidance and control system for a high-spin rocket leads to significant reductions in impact point dispersion.**

**Keywords: rockets, artillery, flight mechanics, guidance, control.**

## I. Introduction

Precision has always been recognized as an important attribute of weapon development. One of the greatest advantages of the precision weapon is the confidence that 'collateral damage' is minimized. In addition, using force in some circumstances would be either unacceptable or call into question the viability of continued military action in absence of precision weapons [1].

A precision-guided munition (PGM) is a guided munition intended to precisely hit a specific target, and to minimize collateral damage. Considering that the damage effects of explosive weapons decrease with distance, even modest improvements in accuracy enable a target to be attacked with fewer or smaller bombs. The precision of these weapons is dependent both on the precision of the measurement system used for location determination and the precision in setting the coordinates of the target. The latter critically depends on intelligence information, not all of which is accurate. If the targeting information is accurate, satellite-guided weapons (including inertial navigation in the event of signal loss) are significantly more likely to achieve a successful strike in any given weather conditions than any other type of precision-guided munition.

Development of low-cost navigation, guidance and control technologies for unguided rockets is a unique engineering challenge. Over the past several decades, numerous solutions have been proposed, primarily for large artillery projectiles or for slowly rolling airframes. Guided projectiles are divided into three categories in terms of the control mechanisms employed: aerodynamic surfaces [3, 4], jet thrusters [2, 5], and inertial loads [6, 7]. Guided projectile concepts involving aerodynamic control surfaces are divided into two categories: fin-stabilized and spin-stabilized. Spin-stabilized guided projectiles are generally equipped with a roll-decoupled trajectory correction fuse, designed to provide trajectory correction, while at the same time the high spin rate of the aft part contributes to airframe stability. However, the high spin rate creates an important coupling between the normal and lateral axes of the body, which makes the dynamic characteristic rather complex. For such projectiles, previous work has proven that flight instabilities occur for spin-stabilized projectiles maneuvering perpendicular to the gravity field when the control effectiveness is sufficiently high [5].

In [8], it is stated that in a guidance system, a suitable guidance law and navigation constant are fundamental elections. Investigation and comparison of the system behavior for guidance laws under different navigation constants are developed. The capture region of the general ideal proportional navigation guidance law is analyzed in [9]. A new longitudinal autopilot to address the finite-time tracking problem is presented in [10]. In [11], it is

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