2D Course Correction System for Spin-Stabilized Projectiles Using a Spoiler Control Surface

6 authors, including:

Pierre Wey
Deutsch-Französisches Forschungsinstitut Saint-Louis
36 PUBLICATIONS 214 CITATIONS

Bastien Martinez
Deutsch-Französisches Forschungsinstitut Saint-Louis
55 PUBLICATIONS 284 CITATIONS

Roxan Cayzac
NEXTER Munitions
61 PUBLICATIONS 441 CITATIONS

Denis Pascal
brawjiaya
86 PUBLICATIONS 1,601 CITATIONS

2D course correction system for spin-stabilized projectiles using a spoiler control surface

P. WEY, B. MARTINEZ, R. CAYZAC[1], E. CARETTE[1], P. DENIS[2], C. GRIGNON[3]

[1] NEXTER Munitions, Technical Direction, Bourges, FR • [2] ONERA, Applied Aerodynamics Department, Meudon, FR
[3] DGA Land Systems, French Ministry of Defense, Bourges, FR

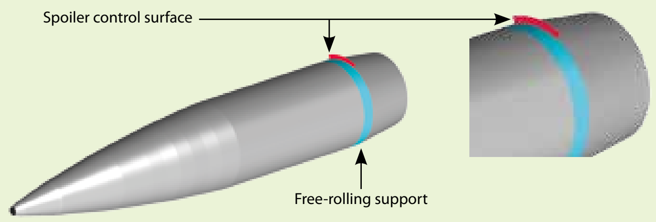
POC: pierre.wey@isl.eu

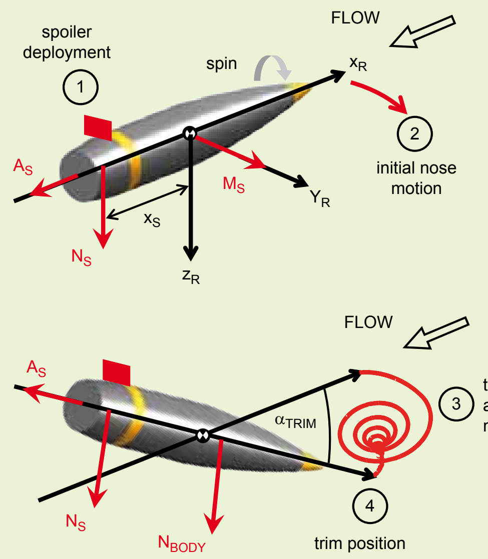
Abstract

Few course control mechanisms have been developed for spin-stabilized projectiles such as artillery shells. Two key challenges must be addressed: the roll angle control of the flow actuator and the pitch and yaw motion of the body caused by the gyroscopic effect. This paper introduces a novel concept of course correction system which consists of a roll-decoupled spoiler surface located aft of the projectile center of mass. The effectiveness of this concept was investigated through an aerodynamic analysis and a seven-degrees-of-freedom trajectory simulation. The control of the spoiler roll angle with respect to a non-rolling frame combined with the control of the deployment time enables a full 2D correction capability. Results show that the ballistic dispersion of 155-mm shells can be corrected for any muzzle velocity and quadrant elevation. In all cases, the spoiler deployment is only required in the last part of the trajectory.

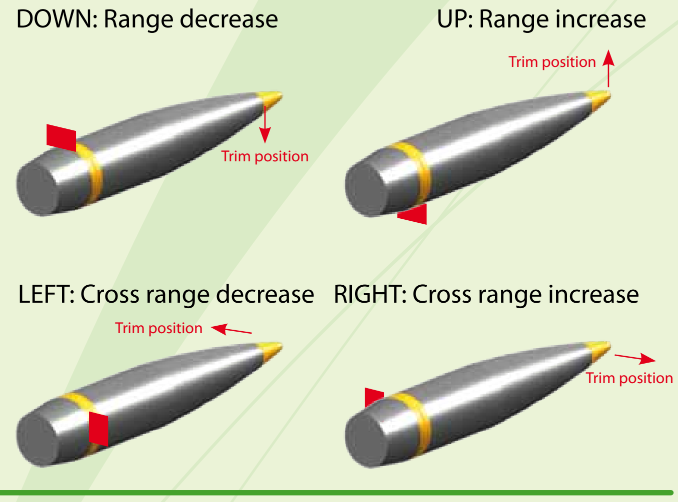
Maneuver concept

- The spoiler control surface is located at the fuselage/boattail junction.
- It can be deployed at any time during flight.
- The spoiler roll position **is fixed** with respect to a non-rolling (plane-fixed) frame:
  – the spoiler and body are connected by means of a free-rolling support ➔ 7-DoF system;
  – some internal mechanism controls the spoiler position at prescribed roll angle.





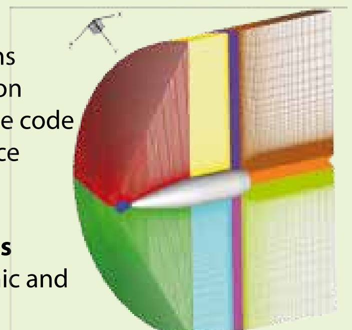
Course deviation resulting from four-quadrant trim positions



Aerodynamic analysis

ONERA's FLU3M code

- 3D Navier-Stokes equations
- RANS and URANS resolution
- Cell-centered finite-volume code
- Spalart-Allmaras turbulence model



Multi-block structured grids

- Grids for subsonic-transonic and supersonic regimes
- 30 to 50 cells in the boundary layer
- Stretching factor < 1.2
- Largest grid: 6 x 10^6 cells, 35 blocks

Conditions

- Mach number = 0.7–3.0
- Angle of attack = 0–3°
- Spoiler: height = 0.075 cal., angular sector = 18°–90°
- No projectile spin

For subsonic and transonic flight conditions, a massive flow separation around the spoiler can be observed. For supersonic flight conditions, the presence of shock waves reduces the separation zone, preventing the possible interaction between the separated flow at the back of the spoiler and the projectile boattail wake.

🡇

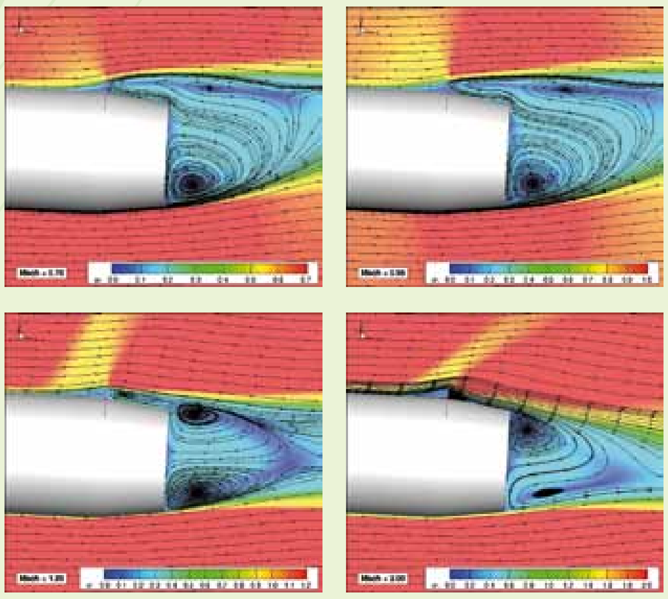
The small spoiler surface can induce large changes in the flow structure, which highlights the high trajectory correction capability of this kind of actuator.

Table of aerodynamic coefficients
(variation due to spoiler deployment)

Mach number	0.70	0.95	1.20	2.00	3.00
Trim angle [deg]	2.76	4.16	1.31	1.18	1.23
Axial force increase	30%	17%	19%	17%	13%
Normal force increase	233%	193%	126%	70%	57%

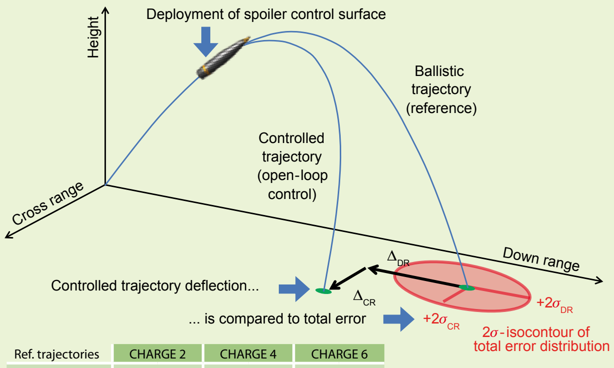
Spoiler normal to the fuselage, height = 0.075 cal.
angular sector = 60°, location from nose = 5.06 cal.

Mach number isocontours



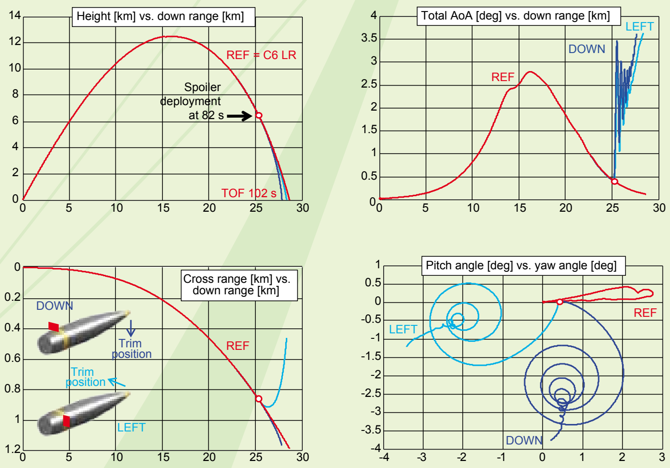
Flight dynamics analysis

BALCO 6/7-DOF Trajectory Model

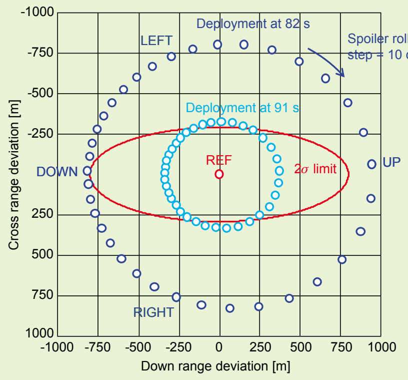


Ref. trajectories	CHARGE 2		CHARGE 4		CHARGE 6	
V_0 [m/s]	467		669		933	
	SR	LR	SR	LR	SR	LR
TOF [s]	21.49	54.54	28.95	69.27	30.16	102.29
Down range [m]	7 328	12 815	11 815	18 860	15 880	28 701
2σ DR error [m]	173	251	265	392	371	803
Cross range [m]	41	254	92	466	122	1 189
2σ CR error [m]	49	100	81	166	104	290

Example of trajectory deflection
(Charge 6, Long range)



Deviation of impact point
(Charge 6, Long range)



Control of spoiler roll angle and deployment time ⇨ Full 2D correction capability

Conclusion and outlook

- The spoiler control surface appears to be a very promising actuator system for the course correction of spin-stabilized artillery shells:
  - 2D dispersion errors can be corrected for any muzzle velocity and quadrant elevation;
  - deployment is required only in the last part of the trajectory.
- Further developments:
  - refined aerodynamic and flight dynamics analyses, including spin and Magnus effects, based on CFD, wind-tunnel and free-flight tests;
  - design of the actuator system: spoiler/body connection, spoiler deployment mechanism, real-time roll angle measurement and control;
  - design of the closed-loop flight control algorithm.

This study was supported by the French Ministry of Defense within the framework of the MANEGE research program.

ISL - PO 770/2014 - DMI/EM (VA) - 08/2014