



US005873549A

# United States Patent [19]

[11] Patent Number: **5,873,549**

Lane et al.

[45] Date of Patent: **Feb. 23, 1999**

## [54] VEHICLE ROTATION AND CONTROL MECHANISM

[75] Inventors: **Jeffery G. Lane**, Irvine; **James R. French**, Los Angeles, both of Calif.

[73] Assignee: **McDonnell Douglas Corporation**, Huntington Beach, Calif.

[21] Appl. No.: **719,457**

[22] Filed: **Sep. 25, 1996**

[51] Int. Cl.<sup>6</sup> ..... **F42B 10/14**; F42B 10/50; F42B 15/01; B64G 1/62

[52] U.S. Cl. .... **244/160**; 244/138 A; 244/139; 244/63; 244/3.28; 102/384; 102/388

[58] Field of Search ..... 244/3.28, 3.29, 244/138 A, 138 R, 139, 160, 164, 63; 102/384, 385, 388

## [56] References Cited

### U.S. PATENT DOCUMENTS

1,324,433	12/1919	Phillips, Jr. ....	102/384
2,840,328	6/1958	Richardson et al. ....	244/113
3,065,937	11/1962	Vigil .	
3,098,445	7/1963	Jackson ..... 244/138 A	
3,118,636	1/1964	Kantrowitz et al. .	
3,181,824	5/1965	Anania ..... 244/160	
3,210,025	10/1965	Lubben et al. .	
3,246,864	4/1966	Mack et al. .... 244/138 A	
3,776,490	12/1973	Weis ..... 244/3.27	
3,903,801	9/1975	Senoski .	

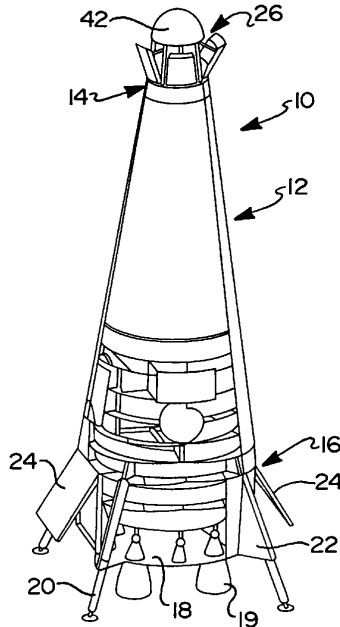
4,007,505	2/1977	Nowatzki .....	244/3.28
4,832,288	5/1989	Kendall et al. .	
4,896,847	1/1990	Gertsch .	
5,031,857	7/1991	Macconochie et al. ....	244/3.28
5,322,248	6/1994	Ragab .	
5,398,888	3/1995	Gerhardt .....	244/3.27

Primary Examiner—V. Lissi Mojica  
Attorney, Agent, or Firm—Harness Dickey & Pierce P.L.C.

## [57] ABSTRACT

A nose assembly and method for controlling the rotation and stabilizing the orientation of a vehicle during landing maneuvers. The vehicle includes a nose assembly that is coupled to an airframe thereof and that has a frame and flap assembly. The flap assembly includes an actuating means and a flap coupled to the frame such that the actuating means moves the flap from and between a fully retracted position and a fully extended position in response to a guidance signal received from a flight control computer. In a preferred embodiment of the present invention, the flap assembly includes a plurality of flaps each coupled to the nose assembly frame and an actuating means that selectively positions the plurality of flaps in response to a signal. The method for rotating a vehicle from a nose-forward orientation to a base-forward orientation includes the steps of orientating the vehicle in nose-forward flight, rotating the vehicle in a first direction, and selectively actuating one of a first and second flap from a retracted position toward an extended position to generate a damping moment tending to position the vehicle in a base-forward orientation.

20 Claims, 3 Drawing Sheets



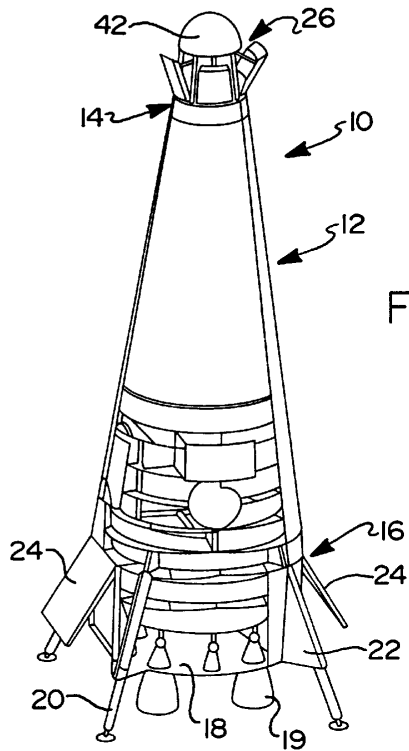


FIG 1

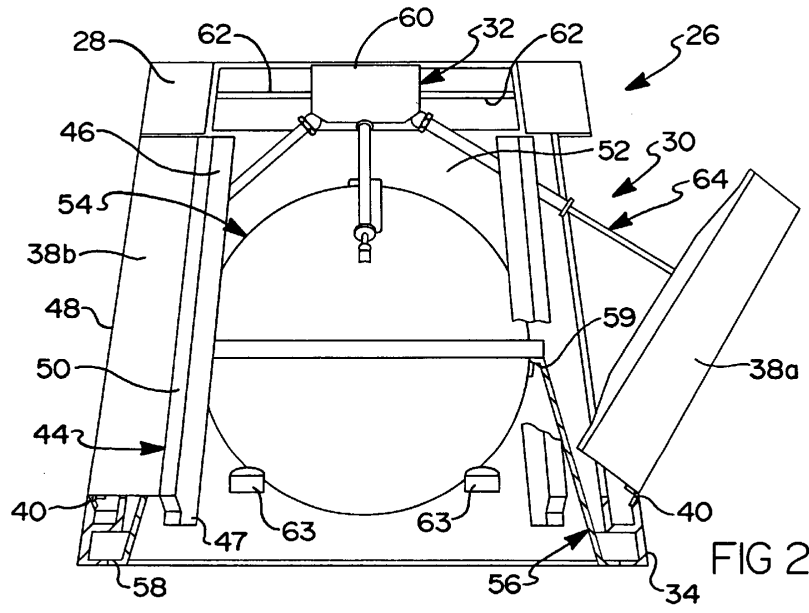


FIG 2

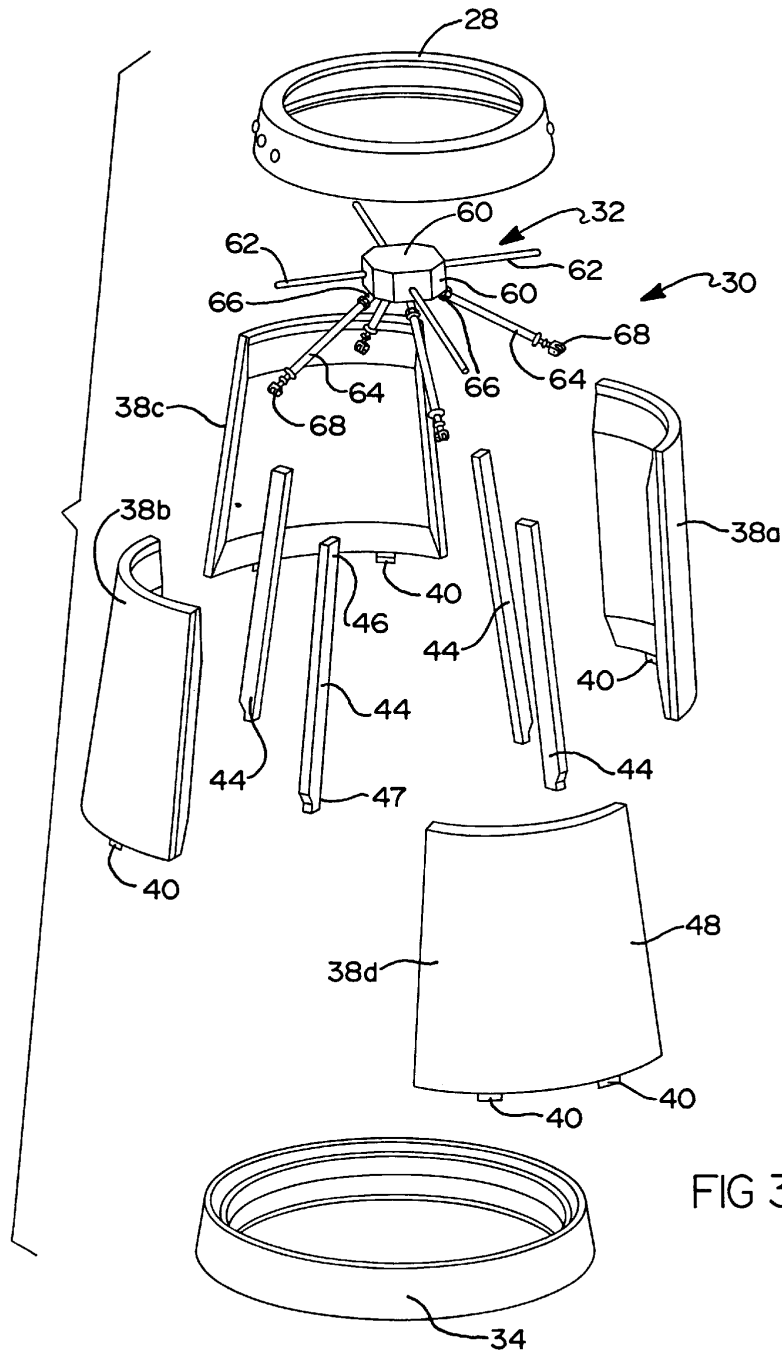


FIG 3

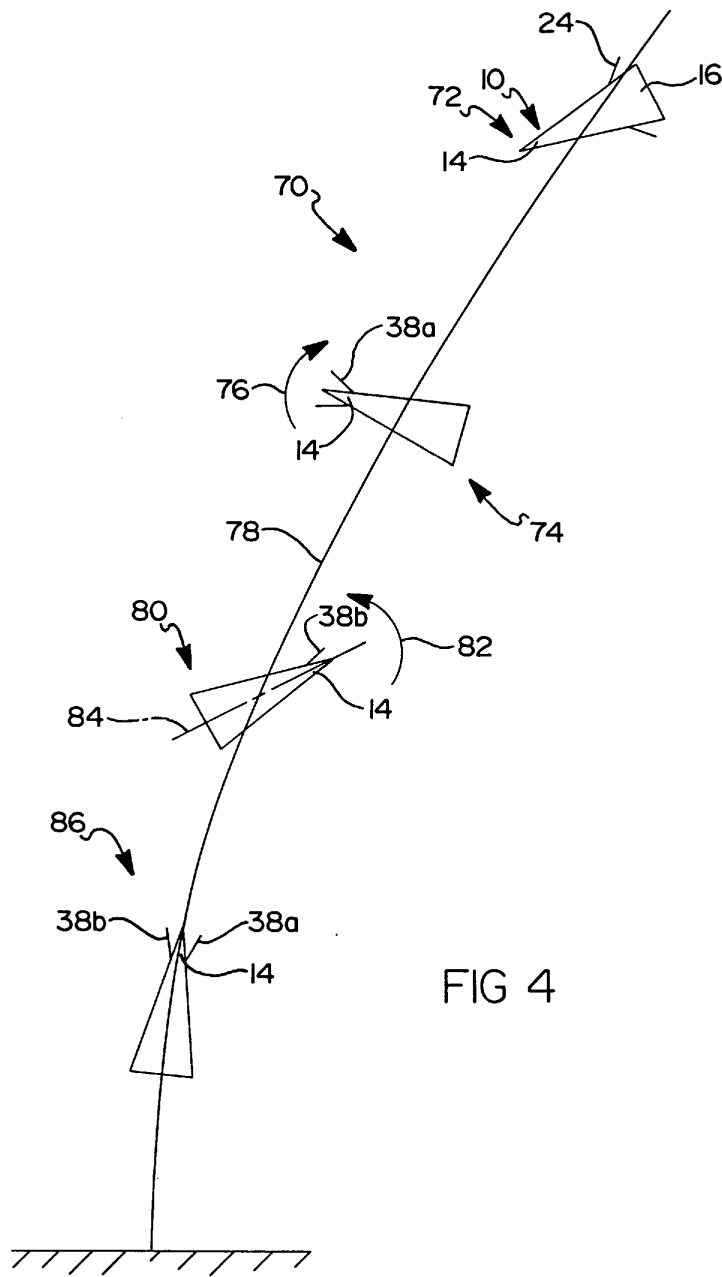


FIG 4

1

## VEHICLE ROTATION AND CONTROL MECHANISM

### BACKGROUND OF THE INVENTION

#### 1. Technical Field

The present invention relates generally to a direction control assembly for an aerospace vehicle and, more particularly, to a flap assembly at the forebody of a reusable launch vehicle for rotating and stabilizing the vehicle during entry and pre-landing maneuvers.

#### 2. Discussion

Reusable launch vehicles used to deploy satellites in a predetermined orbit about the earth include single stage to orbit ("SSTO") vehicles that are designed to perform their intended operation and return to earth without jettisoning any portions of the vehicle. Accordingly, SSTO vehicles do not include discardable booster rockets or fuel tanks. Rather, the fuel supply elements of SSTO vehicles are retained throughout the flight thereby increasing the need to minimize fuel consumption in order to decrease the unusable weight carried into orbit. The present invention addresses these concerns by providing a vehicle rotation and control mechanism that reduces propellant acquisition subsystems and the propellant required to properly position the vehicle for landing.

Vertically landing SSTO vehicles commonly include a conically shaped airframe configured for stable flight in a nose-forward orientation. However, since the vehicle is vertically landed in a rearward or tail-first orientation a rotation of the vehicle during the landing sequence is required. Currently, SSTO vehicles of this class perform the rotation maneuver through the use of engine power. More specifically, the maneuver includes starting several of the main engines, retracting entry flaps so that the vehicle pitches up to initiate rotation, and selectively throttling up the engines to arrest rotation and place the vehicle into the desired base-first orientation. In order to minimize the quantity of propellant consumed by the engines between the rotation and touch down phases of the landing procedure, this rotation maneuver is generally conducted at a relatively low altitude. While this procedure is viable, a considerable amount of propellant is used during the starting and operation of the engines and the propellant feed system becomes heavy and complex. Further, the relatively low altitude compresses landing functions into a shorter timeline.

### SUMMARY OF THE INVENTION

The present invention provides a nose assembly and method for controlling the rotation and stabilizing the orientation of an aerospace vehicle during landing maneuvers. The vehicle includes a nose assembly that is coupled to an airframe and that has a frame and flap assembly. The flap assembly includes an actuating means and a flap coupled to the frame such that the actuating means moves the flap from and between a fully retracted position and a fully extended position in response to a guidance signal received from the flight control computer. In a preferred embodiment of the present invention, the flap assembly includes four of flaps each coupled to the nose assembly frame and an actuating means that selectively positions each flap in response to a signal. A method for rotating the vehicle from a nose-forward orientation to a base-forward orientation according to the present invention includes the steps of orientating the vehicle in nose-forward flight, rotating the vehicle in a first direction, and selectively actuating one of a first and second flap to an extended position to generate a damping moment tending to position the vehicle in a base-forward orientation.

2

## BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings, in which:

FIG. 1 is a perspective view of a reusable launch vehicle in accordance with the present invention;

FIG. 2 is a front partial sectional view of the nose cone of the vehicle shown in FIG. 1 with a flap removed for clarity;

FIG. 3 is an exploded perspective view of the nose cone shown in FIG. 2; and

FIG. 4 is a schematic illustrating the orientation and nose flap position during the landing rotation sequence of the single stage to orbit vehicle shown in FIG. 1.

### DETAILED DESCRIPTION

The following description of the preferred embodiment of the present invention is merely exemplary in nature and is not intended to limit the scope of the claimed invention. Moreover, while depicting the invention in a single stage to orbit ("SSTO") vehicle, the description is intended to adequately teach one skilled in the art to make and use the vehicle rotation and control mechanism and method described and claimed herein in a variety of aerospace vehicles.

As illustrated in FIG. 1 of the drawings, a vertically landing reusable launch vehicle 10 includes a generally conical shaped airframe 12 defining a forebody 14 and a thrust structure 16. Thrust structure 16 includes a base 18 proximate to which landing gear 20, fins 22, and rear flaps 24 are coupled to airframe 12. The forward portion of rear flaps 24 are pivotably connected to airframe 12 in a manner known in the art and an actuating mechanism (not shown) communicates with a flight control computer (not shown) and is coupled to rear flaps 24 to control the angular position thereof relative to airframe 12. During normal, nose-first flight, the flight computer selectively positions rear flaps 24 to stabilize the flight path and orientation of vehicle 10.

Forebody 14 of airframe 12 includes a nose cone 26 that is shown in FIGS. 2 and 3 to include a flap assembly 30 having a flap actuating apparatus 32 connected to an upper bulkhead ring 28. Nose cone 26 further includes a lower bulkhead ring 34, a plurality of flaps 38a, 38b, 38c, and 38d pivotably connected to lower ring 34 via hinge assemblies 40, a cap 42 (FIG. 1) securable to upper ring 28 in a manner known in the art, and stringers 44 having a first end 46 connected to upper bulkhead 28 and a second end 47 configured to cooperate with lower bulkhead 34. Assembly 30 preferably includes four (4) circumferentially opposed and separately operable flaps that form flap pairs capable of providing opposing damping moments during vehicle flight. As best seen in FIG. 2, flaps 38a and 38b illustrate one of the pair of opposed flaps wherein flap 38a is shown in a fully extended or fully pivoted position whereas flap 38b is fully retracted. In a manner known in the art, actuating apparatus 32 selectively positions flaps 38a and 38b at or between the fully extended and fully retracted positions in response to an input signal received from the vehicle's flight computer (not shown).

When constructed as described herein and as best seen in FIG. 2, cap 42, upper ring 28, an outer surface 48 of flaps 38, and a radially outer surface 50 of stringers 44 cooperate to define a relatively smooth and aerodynamic outer surface surrounding a cavity 52. In the preferred embodiment, cavity 52 houses an auxiliary liquid oxygen tank 54 and actuating apparatus 32. More particularly, a conical support 56 is

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

## LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

## FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

## E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.