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(54) **AUGMENTED EM PROPULSION SYSTEM**

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(57) **ABSTRACT**

An electromagnetic missile launcher is disclosed that avoids some of the costs and disadvantages of missile launchers in the prior art. In particular, an embodiment of the present invention uses a pilot accelerator that comprises an electromagnetic booster coil to improve the efficiency of an electromagnetic catapult that throws a missile clear of the launch platform—with sufficient velocity to attain aerodynamic flight—before the missile's engine is ignited.

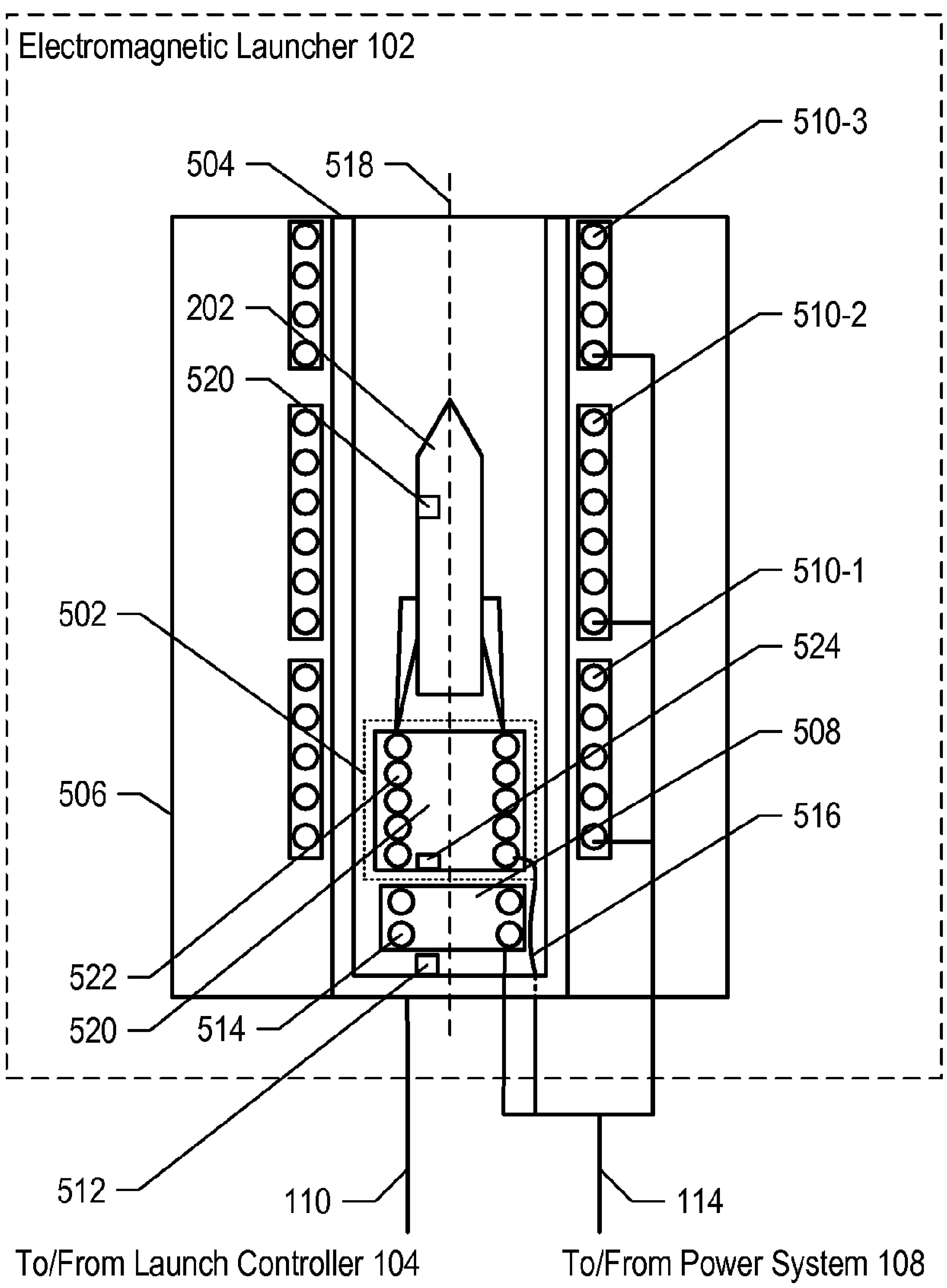


Figure 1

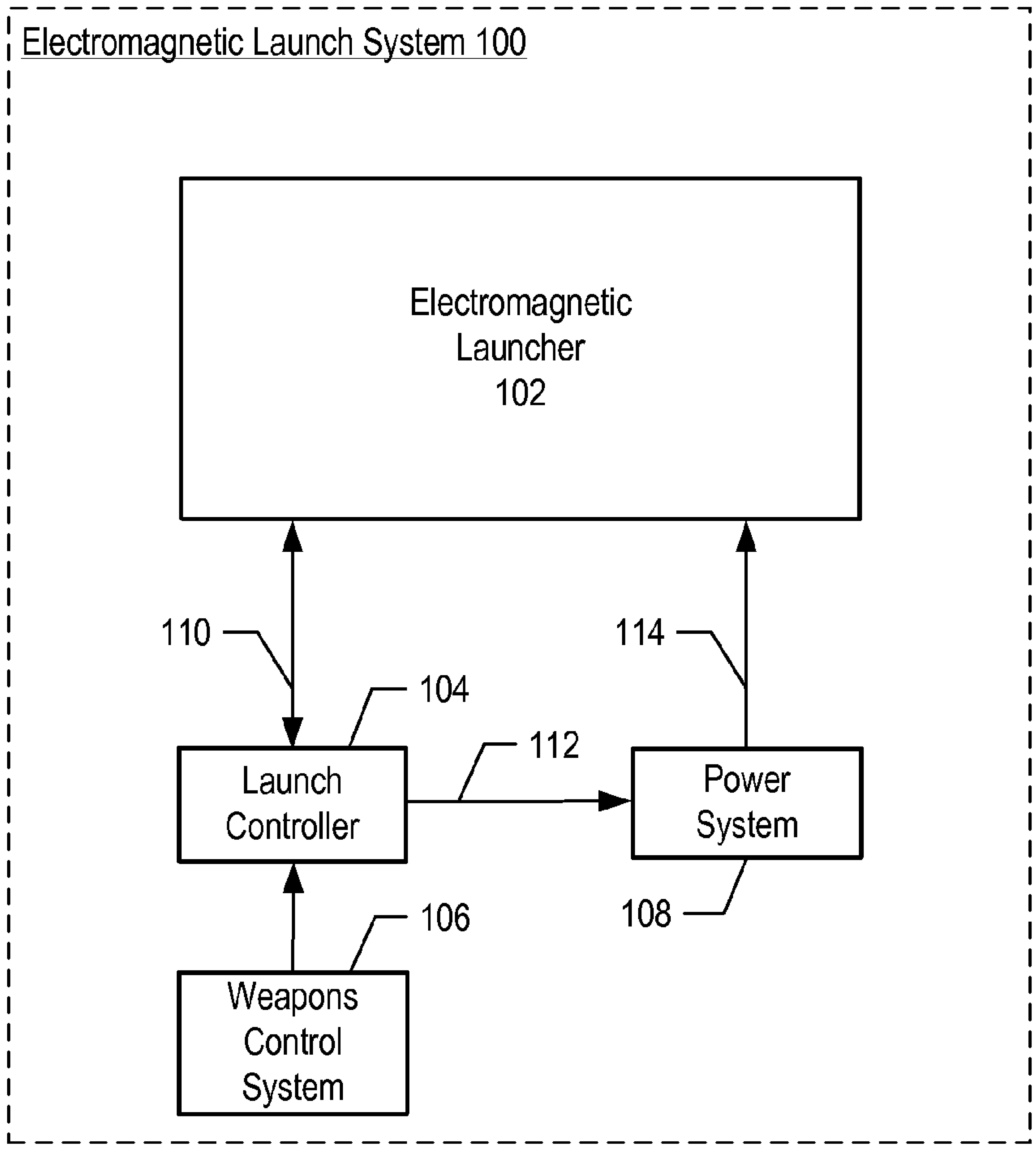

Electromagnetic Launch System 100
Electromagnetic
Launcher
102
110
114
104
112
Launch
Controller
Power
System
106
108
Weapons
Control
System

Figure 2 (Prior Art)

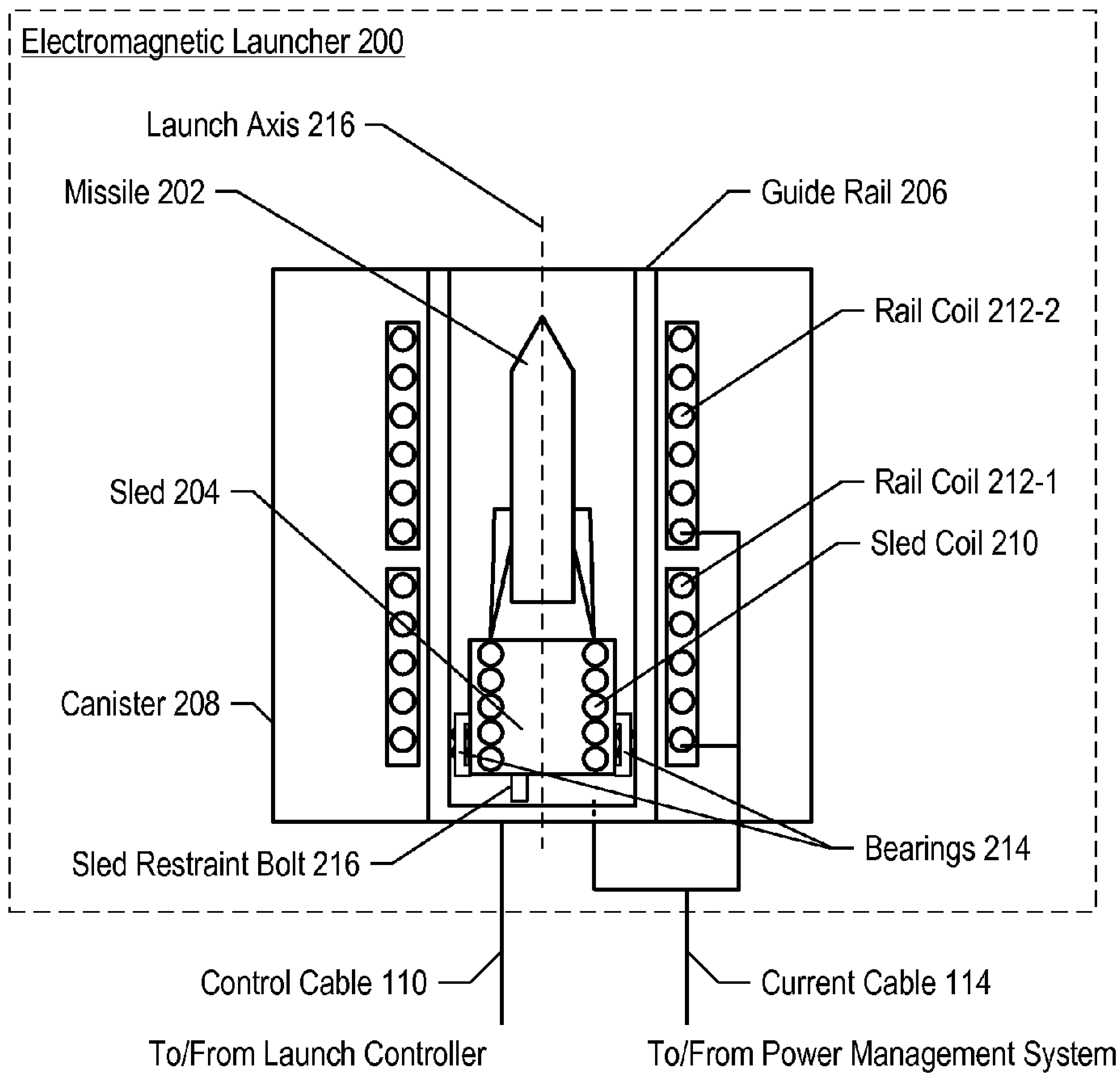


Figure 3 (Prior Art)

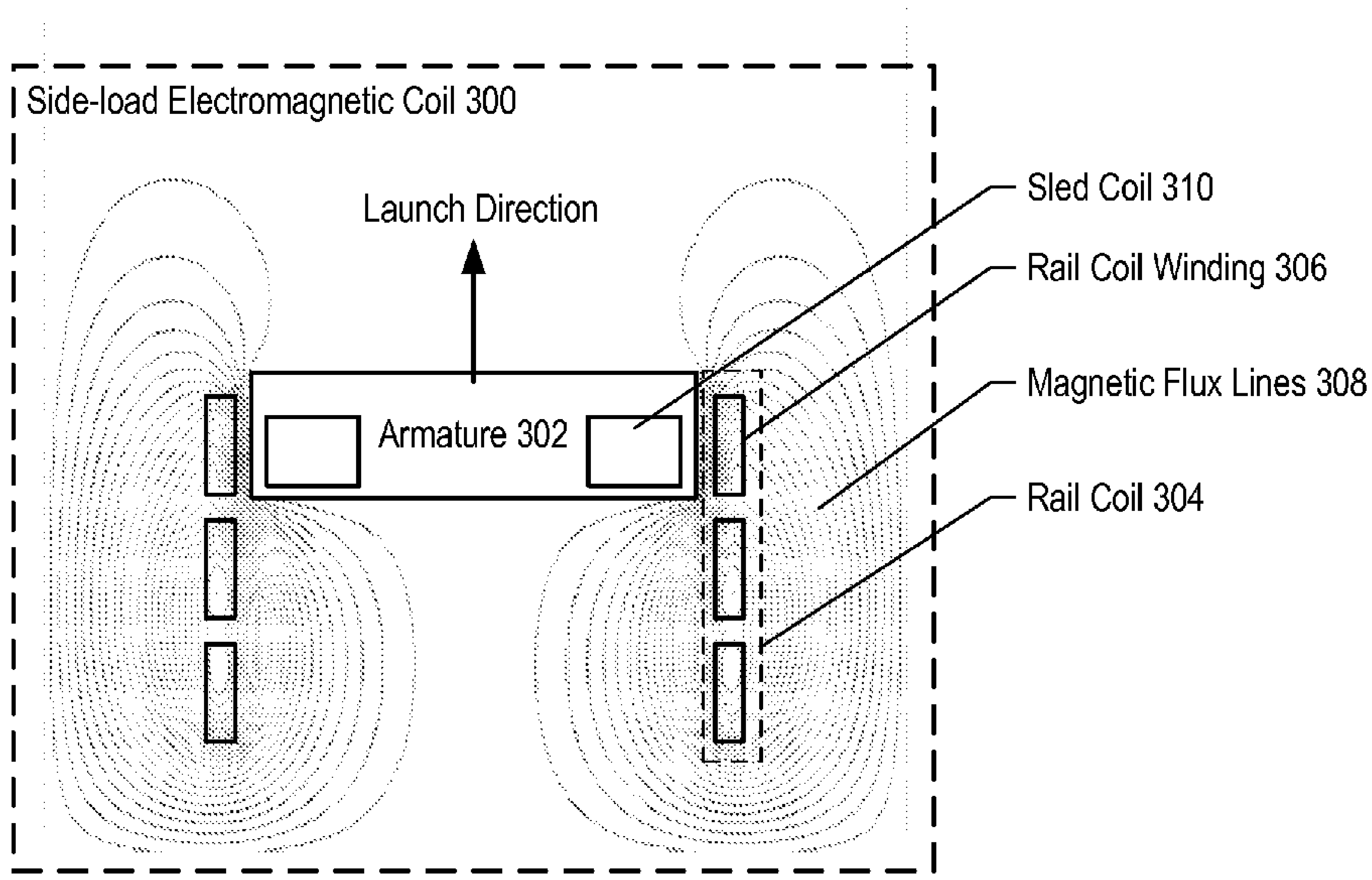


Figure 4

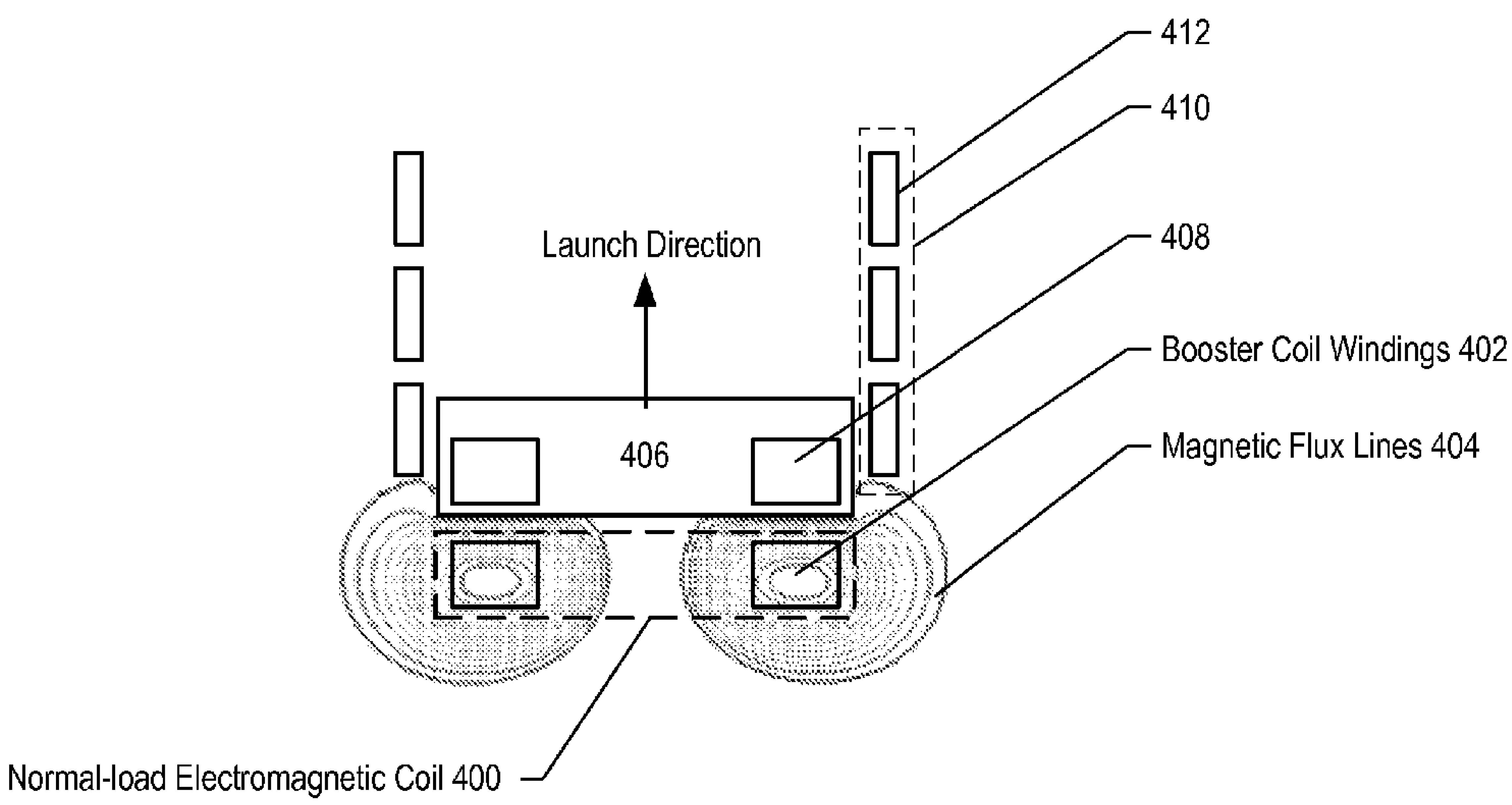

412
410
Launch Direction
408
Booster Coil Windings 402
406
Magnetic Flux Lines 404
Normal-load Electromagnetic Coil 400

Figure 5

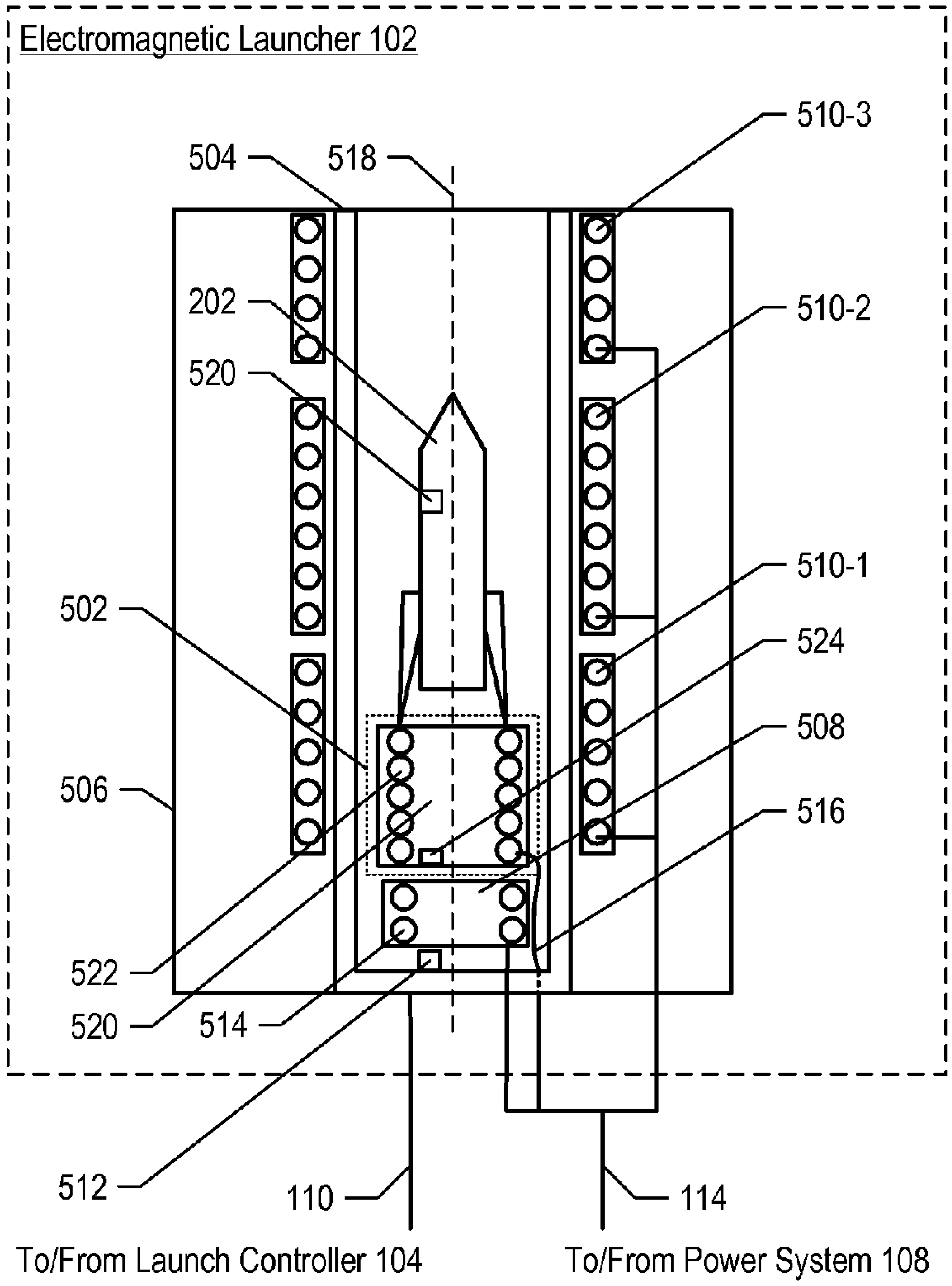
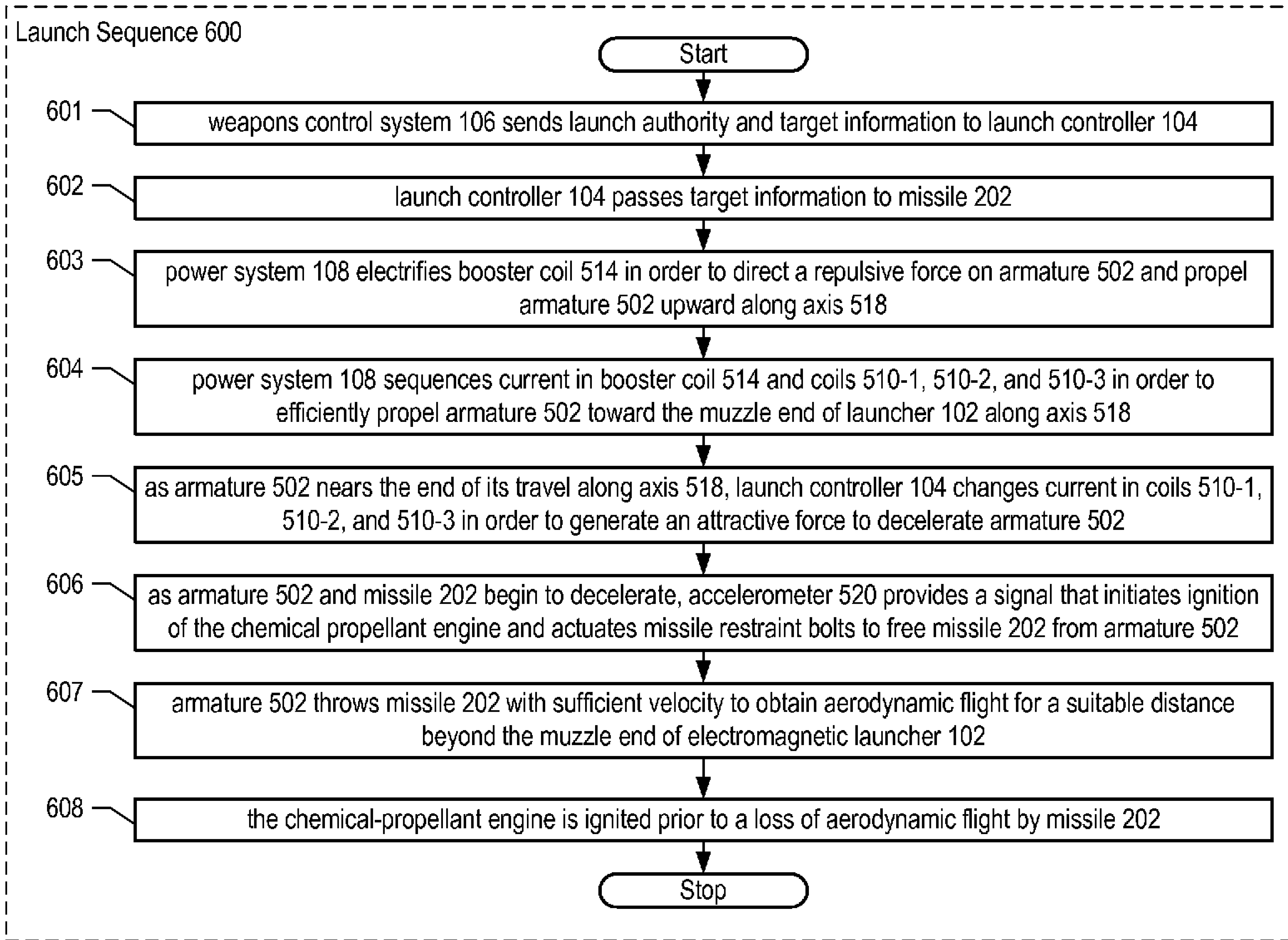

Electromagnetic Launcher 102
510-3
504
518
202
510-2
520
510-1
502
524
508
506
516
522
520
514
512
110
114
To/From Launch Controller 104
To/From Power System 108

Figure 6


Launch Sequence 600
Start
601
weapons control system 106 sends launch authority and target information to launch controller 104
602
launch controller 104 passes target information to missile 202
603
power system 108 electrifies booster coil 514 in order to direct a repulsive force on armature 502 and propel armature 502 upward along axis 518
604
power system 108 sequences current in booster coil 514 and coils 510-1, 510-2, and 510-3 in order to efficiently propel armature 502 toward the muzzle end of launcher 102 along axis 518
605
as armature 502 nears the end of its travel along axis 518, launch controller 104 changes current in coils 510-1, 510-2, and 510-3 in order to generate an attractive force to decelerate armature 502
606
as armature 502 and missile 202 begin to decelerate, accelerometer 520 provides a signal that initiates ignition of the chemical propellant engine and actuates missile restraint bolts to free missile 202 from armature 502
607
armature 502 throws missile 202 with sufficient velocity to obtain aerodynamic flight for a suitable distance beyond the muzzle end of electromagnetic launcher 102
608
the chemical-propellant engine is ignited prior to a loss of aerodynamic flight by missile 202
Stop

AUGMENTED EM PROPULSION SYSTEM

[0001] This invention was made with Government support under Cooperative Research and Development Agreement No. SC99/01573 awarded by the Department of Energy. The Government has certain rights in the invention.

FIELD OF THE INVENTION

[0002] The present invention relates to missilery in general, and, more particularly, to missile launchers.

BACKGROUND OF THE INVENTION

[0003] A missile is propelled by fuel and a chemical-propulsion engine. A chemical-propulsion engine propels a missile by the reaction that results from the rearward discharge of gases that are liberated when the fuel is burned. For the purposes of this specification, a "missile" is defined as a projectile whose trajectory is not necessarily ballistic and can be altered during flight (as by a target-seeking radar device and control elements).

[0004] When a missile is launched, the discharge of the hot gases causes several problems. First, the hot gases heat the launch platform, which renders the launch platform more visible to enemy infrared sensors and, therefore, more vulnerable to attack. Second, the hot gases can obscure the ability of personnel in the area of the launch platform to see, which might impair their ability to perform routine tasks, such as detecting enemy threats. Third, the brightness of the flame exiting the engine can—especially at night—temporarily blind the launch-platform personnel. Fourth, the missile's fuel often includes an aluminized compound that is dispersed in the atmosphere surrounding the launch platform, which can impair the operation of radar systems near the launch platform. And fifth, as modern missiles become larger, their gases become hotter and more voluminous, and, therefore, cannot be adequately vented within the launching platform using current technology.

[0005] Electromagnetic missile launchers (EMMLs) have been developed to mitigate some of the damaging effects of a chemically-based missile launch, In the prior art, such as U.S. patent application Ser. No. 10/899,234, filed on 26 Jul. 2004, which is incorporated by reference herein, an EMML typically utilizes electromagnetic coils around a guide rail to propel an armature on which is mounted to a missile. Inefficiencies inherent to this propulsion method, however, dictate that the electromagnetic coils be larger, more numerous, and carry more electric current than desirable. The additional infrastructure adds to launcher cost and complexity. In addition, the power system used to control the flow of electric current in the electromagnetic coils must be made larger so as to manage the increased electric current as well as transients that develop through the course of a missile launch. There exists a need, therefore, for a missile launch system that avoids or mitigates some or all of these problems.

SUMMARY OF THE INVENTION

[0006] The present invention provides a technique for launching a missile that avoids some of the costs and disadvantages for doing so in the prior art. In particular, the illustrative embodiment of the present invention uses a pilot accelerator to accelerate an armature for throwing a missile from its rest position into motion toward a series of rail coils that sustain the acceleration of the armature.

[0007] In the illustrative embodiment, an electromagnetic coil arrangement includes a propulsion coil—the pilot accelerator—that is located behind the missile armature so as to direct its propulsive force on the armature along the launch axis. This provides a more efficient means of initiating the motion of the armature than is known in the prior art. The coupling efficiency of the electromagnetic force generated by the rail coils is improved by the use of the pilot accelerator, which results in an improvement in efficiency of the overall launcher system. This mitigates some of the problems associated with launching missiles in the prior art.

[0008] An embodiment of the present invention comprises: an outer coil that has a longitudinal axis; an armature that comprises an armature coil that is concentric with the outer coil, wherein the outer diameter of the armature coil is smaller than the inner diameter of the outer coil; and a pilot accelerator for imparting a first force to the armature, wherein the first force is directed along the longitudinal axis of the outer coil; wherein a second force on the armature is based on the mutual inductance of the outer coil and the armature coil; and wherein the first force accelerates the armature from a rest position toward the outer coil so as to increase the mutual inductance of the outer coil and the armature coil.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** depicts a schematic diagram of an electromagnetic launch system in accordance with an embodiment of the present invention.

[0010] FIG. **2** depicts a cross-sectional view of an electromagnetic missile launcher in accordance with the prior art.

[0011] FIG. **3** depicts a cross-sectional view of a side-load electromagnetic coil in accordance with the prior art.

[0012] FIG. **4** depicts a cross-sectional view of a normal-load electromagnetic coil in accordance with an embodiment of the present invention.

[0013] FIG. **5** depicts a cross-sectional view of an electromagnetic launcher according to an embodiment of the present invention.

[0014] FIG. **6** depicts a flowchart of the salient tasks associated with a representative launch sequence, in accordance with the illustrative embodiment of the present invention.

DETAILED DESCRIPTION

[0015] The following terms are defined for use in this Specification, including the appended claims:

[0016] Physically-connected means in direct, physical contact and affixed (e.g., a mirror that is mounted on a linear-motor).

[0017] Physically-coupled means in direct, physical contact, although not necessarily physically-connected (e.g., a coffee cup resting on a desktop).

[0018] Pilot accelerator means a device or structure for imparting acceleration to an armature. Examples of pilot accelerators include, without limitation, a compressed gas system, an explosive charge, or a mechanical-energy storage device, such as a spring. Examples of pilot accelerators do not include a side-coupled electromagnetic coil (i.e., a rail coil).

[0019] FIG. **1** depicts a schematic diagram of an electromagnetic launch system in accordance with an embodiment of the present invention. Electromagnetic launch system **100** comprises electromagnetic launcher **102** (hereinafter, launcher **102**), launch controller **104**, weapons control system **106**, power system **108**, control cable **110**, signal line **112**, and current cable **114**.

[0020] Launcher **102** is a system that has the capability to house and expel one or more missiles upon command. The system expels each missile from an associated launch cell using an electromagnetic catapult and without the aid of the missile's chemical-propulsion engine. This is advantageous because it enables the missile to clear the launch platform before it ignites its engine, thereby avoiding some of the problems discussed in the Background section. Although in the illustrative embodiment electromagnetic launch system **100** comprises an electromagnetic launcher having a single launch cell, it will be clear to those skilled in the art, after reading this specification, how to make and use alternative embodiments of the present invention wherein launcher **102** comprises more than one launch cell.

[0021] Launch controller **104** provides the targeting and flight information to a missile prior to launch and the directive to launch to power system **108**.

[0022] Weapons control system **106** provides targeting and flight information and firing authority to launch controller **104** prior to and during a launch sequence. It will be clear to those skilled in the art, after reading this disclosure, how to make and use weapons control system **106**.

[0023] Power system **108** comprises circuitry that conditions and manages the storage and delivery of power to, and the recover of power from, launcher **102** in response to signals from launch controller **104**. Power system **108** controls power generation, scavenging, storage, and delivery prior to, during, and after each launch. Power system **108** is described in detail in U.S. patent application Ser. No. 10/899,234, filed on 26 Jul. 2004, which is incorporated by reference herein.

[0024] Control cable **110** carries the targeting information from launch controller **104** to the missile and sled position information from sled-position sensor **322** (shown in FIG. **3**) to launch controller **104**.

[0025] Signal line **112** connects launch controller **104** to power system **108** and carries the commands that direct power system **108** to initiate and control the launch of a missile.

[0026] Current cable **114** carries power from power system **108** to launcher **102**. In some embodiments of the present invention that comprise multiple launch cells, current cable **114** is capable of carrying power to each launch cell independently from the other launch cells.

[0027] FIG. **2** depicts a cross-sectional view of an electromagnetic missile launcher in accordance with the prior art. Electromagnetic launcher **200** (hereinafter, launcher **200**) comprises missile **202**, sled **204**, guide rail **206**, missile canister **208**, sled coil **210**, and rail coils **212-1** and **212-2**. As described in U.S. patent application Ser. No. 10/899,234, during a missile launch, launcher **200** throws missile **202** with sufficient velocity to obtain aerodynamic flight such that missile **202** travels some distance away from launcher **200** before the missile's chemical-propulsion engine ignites.

[0028] Missile canister **208** encloses missile **202**, sled **204**, guide rail **206**, and rail coils **212-1** and **212-2** in a substantially air-tight environment.

[0029] Missile **202** comprises a chemical-propulsion engine and an explosive warhead.

[0030] Sled **204** comprises a rigid platform for holding a missile, sled coil **210**, and bearings **214** for guiding sled **204** along guide rail **206**. Sled coil **210** is an electrical conductor that has a helical shape and is immovable with respect to sled **204**. Prior to launch, missile **202** is attached to sled **204** by actuatable missile restraint bolts (not shown for clarity) and sled **204** is attached to missile canister **208** by sled restraint bolt **214**.

[0031] Rail coils **212-1** and rail coil **212-2** each comprise a helix of electrical conductor, wherein each helix has an inner diameter larger than the outer diameter of the sled coil, and wherein the electrical conductor is capable of carrying sufficiently high voltage/amperage to enable sufficient launch power.

[0032] During a missile launch, electric current is first directed to flow through sled coil **210** and rail coil **212-1** by a power management system. The current flow induces a force on sled **204** that is partially directed along launch axis **216**. The magnitude of the electromagnetic force on sled **204** is a function of the currents in sled coil **210** and rail coil **212-1** and the gradient of their mutual inductance. The electromagnetic force increases until it is sufficient to break sled restraint bolt **216** and propel sled **204** (and attached missile **202**) along launch axis **218** toward the muzzle end of launcher **200**. The power management system sequences and controls current flow in sled coil **210**, rail coil **212-1** and rail coil **212-2** during missile launch to continue the acceleration of sled **204** along launch axis **218** until sufficient velocity is obtained to throw missile **202**. At a predetermined velocity, the missile restraint bolts are actuated (i.e., broken) and the power management system changes the current flow in sled coil **204** and rail coils **212-1** and **212-2** so as to decelerate sled **204** such that the missile disengages from the sled. After it disengages from sled **204**, missile **202** exits the muzzle end of launcher **200** and achieves aerodynamic flight. Prior to the loss of aerodynamic flight, and after missile **202** achieves sufficient separation from launcher **200**, the chemical-propulsion engine of the missile is ignited and missile **202** continues toward its target.

[0033] At the beginning of the launch sequence, the electromagnetic force on sled **204** is generated by the flow of electric current in the sled coil and rail coils. The magnitude of that force is a function of the mutual inductance of these coils. Rail coils **212-1** and **212-2** are "side-load" electromagnetic propulsion elements, as will be described below and with respect to FIG. **3**. The electromagnetic force generated by side-coil elements is not efficiently coupled into motion of sled **204** along launch axis **218**. The coupling of the mutual inductance of sled coil **210** and rail coils **212-1** and **212-2** is particularly inefficient when sled **204** is in its rest position at the breech end of launcher **200**. Unfortunately, the acceleration of missile **202** from rest (and breaking sled restraint bolts **216**) is the least efficient step in the launch sequence for converting electrical energy to kinetic energy—much less efficient than the energy conversion required for accelerating an already moving missile **202**. Because of the need to perform this inefficient conversion (necessary only at the beginning of a launch), more rail coils or rail coils **212-1** and **212-2** need to be made larger and more complex than would be required to accelerate a missile already in motion. The added infrastructure, including a more powerful power management system, increases the size, weight, cost, and complexity of launcher **200**.

[**0034**] The mutual inductance between a coil and an armature is a function of the number of coil windings and the magnitude of the electric current flowing in the coil. The force exerted between the coil and armature arises from a gradient in the mutual inductance between them. The directionality of that force is a function of the relative positions of the coil and armature (i.e., the way the electromagnetic field couples to the armature). The rail coils described above are examples of "side-load" electromagnetic coils. Much of the force generated between a side-load coil and an armature is in the direction between the coil and the armature. In the case of an electromagnetic missile launcher, however, it is most desirable to direct the force applied to an armature along the launch axis of the missile launcher.

[**0035**] In a maximally-efficient electromagnetic missile launch system, all of the generated electromagnetic force is directed along the launch axis. As is described below and with respect to FIG. **4**, a "normal-load" electromagnetic coil substantially increases the portion of generated electromagnetic force applied to an armature along the launch axis. In the present invention, a normal-load electromagnetic coil is used as a pilot accelerator to accelerate an armature from its rest position toward a series of concentric side-load electromagnetic coils (i.e., rail coils). The rail coils sustain the acceleration of the armature in known fashion.

[**0036**] FIG. **3** depicts a cross-sectional view of a side-load electromagnetic coil in accordance with the prior art. Side-load electromagnetic coil **300** comprises rail coil **304** and its rail coil windings **306**. Magnetic flux lines **308**, generated in response to the flow of electric current in rail coil windings **306**, are influenced by the presence of armature **302** and have the characteristic shape as shown. A significant amount of the electromagnetic force applied to armature **302** is directed between sled coil **310** and rail coil windings **306**, rather than along the launch direction. As a result, side-load rail coil **300** propels armature **302** along the launch direction with less than maximum efficiency.

[**0037**] FIG. **4** depicts a cross-sectional view of a "normal-load" electromagnetic coil in accordance with an embodiment of the present invention. Normal-load electromagnetic coil **400** comprises booster coil windings **402**. Magnetic flux lines **404** are generated in response to the flow of electric current in booster coil windings **402**, and are influenced by the presence of armature **302**. In the case of normal-load electromagnetic coil **400**, the launch direction is aligned with the direction of the majority of the generated electromagnetic force. As a result, normal-load electromagnetic coil **400** propels armature **406** along the launch direction with higher efficiency than side-load electromagnetic coil **300**.

[**0038**] Since it is more efficient, the arrangement of propulsion coils depicted in FIG. **4** enables a reduction in at least some of size, weight, number of turns, magnitude of current flow, and complexity of power system for electromagnetic launch system **100**, as compared to those known in the prior art.

[**0039**] FIG. **5** depicts a cross-sectional view of an electromagnetic launcher according to an embodiment of the present invention. Launcher **102** comprises missile **202**, armature **502**, guide rail **504**, missile canister **506**, pilot accelerator **508**, rail coils **510-1** through **510-3**, sled-position sensor **512** and current umbilical **516**.

[**0040**] Missile canister **506** provides a substantially airtight environment for missile **202**, armature **502**, guide rail **504**, pilot accelerator **508**, rail coils **510-1** through **510-3**, and current umbilical **516**, in well-known fashion. In some alternative embodiments of the present invention, some of pilot accelerator **508** and rail coils **510-1**, **510-2**, and **510-3** are located outside missile canister **506**.

[**0041**] Missile **202** comprises an explosive warhead, a chemical-propellant engine, and accelerometer **520** for providing acceleration information as is well-known in the art. It will be clear to those skilled in the art, after reading this disclosure, how to make and use missile **202**.

[**0042**] Armature **502** comprises sled **520**, sled coil **522**, and reflector **524**. Sled **520** comprises a rigid platform of suitable size for supporting missile **202**. Sled coil **522** comprises a helical coil of electrical conductor, capable of carrying sufficiently high voltage/amperage to enable sufficient launch power, and sled coil **522** is substantially immovable with respect to sled **520**. The mutual inductance of sled coil **522** and booster coil **514** generates an electromagnetic force along axis **518** when booster coil **514** is energized with electric current. In similar fashion, the mutual inductance of sled coil **522** and each of rail coils **510-1** through **510-3** generates an electromagnetic force along axis **518** when one or more of rail coils **510-1** through **510-3** is energized with electric current. Reflector **524** is a mirror for reflecting an optical beam back to sled-position sensor **512** in known fashion. In some embodiments of the present invention, sled coil **514** is carries electric current supplied by power system **108**. In these embodiments, the direction of electromagnetic force generated by sled coil **522** along axis **518** depends on the direction of current flow in sled coil **522**.

[**0043**] Prior to a launch, armature **502** is rigidly attached to missile canister **506** by a sled restraint bolt, and missile **202** is attached to armature **502** by missile restraint bolts. Bearings for guiding armature **502** along guide rail **504**, the missile restraint bolts, and the sled restraint bolt are not shown for clarity. It will be clear to those skilled in the art how to make and use sled bearings, missile restraint bolts, and sled restraint bolts. It will be clear to those skilled in the art, after reading this disclosure, how to make and use armature **502**.

[**0044**] Guide rail **504** comprises four vertical members that provide structural support for missile canister **506**, pilot accelerator **508**, and rail coils **510-1** through **510-3** which are affixed to guide rail **504** in a substantially-immovable manner. Guide rail **504** also provides straight, smooth tracks against which the sled bearings ride during a launch.

Although the illustrative embodiment comprises four (4) vertical structural members, it will be clear to those in skilled in the art, after reading this disclosure, how to make and use embodiments of the present invention that comprise any number of vertical structural members.

[0045] Pilot accelerator **508** is located behind the rest position of armature **502** on axis **518** and comprises booster coil **514**. Booster coil **514** is a helix of electrical conductor capable of carrying sufficiently high voltage/amperage to enable sufficient electromagnetic energy to: (1) initiate motion of armature **502** from a rest position; and (2) propel armature **502** into a suitable position for continued acceleration by electromagnetic force generated by rail coil **510-1**. Booster coil **514** generates electromagnetic force along axis **518** when energized with electric current. The direction of electromagnetic force generated along axis **518** by booster coil **514** depends on the direction of current flow in the coil. It will be clear to those skilled in the art, after reading this disclosure, how to make and use booster coil **514**.

[0046] Current umbilical **516** comprises electrical conductors of sufficient length to span the length of travel of armature **502** during a launch. Current umbilical **516** is electrically-connected to current cable **114** and provides electrical connection of armature **502** to power system **108** throughout the entire launch. Prior to the launch, targeting information is passed from launch controller **104** to missile **202** via a canister-to-sled umbilical and sled-to-missile umbilical in similar fashion to current cable **516**. For the sake of clarity, these umbilical lines are not shown in FIG. **5**. It will be clear to those skilled in the art how to make and use current umbilical **516**, and canister-to-sled and sled-to-canister umbilicals.

[0047] Although the embodiment depicted in FIG. **5** employs an electromagnetic booster coil to provide pilot acceleration (i.e., acceleration of armature **502** from rest toward rail coil **510-1**), in some alternative embodiments of the present invention, a non-electromagnetic means of accelerating the armature from rest is provided. Suitable means for providing pilot acceleration include, without limitation, mechanical springs, compressed gas or fluid, or explosive force. In some alternative embodiments of the present invention, wherein pilot acceleration is provided in a non-electrical manner, current umbilical **516** is unnecessary.

[0048] Rail coils **510**-*i*, where i=1 to 3, each comprise a helix of electrical conductor, wherein each helix has an inner diameter larger than the outer diameter of sled coil **522**, and wherein the electrical conductor is capable of carrying sufficiently high voltage/amperage to enable sufficient launch power. Each rail coil **510**-*i* generates electromagnetic force along axis **518** when energized with electric current. The direction of electromagnetic force that is generated along axis **518** by each of rail coils **510**-*i* depends on the direction of current flow in that coil. It will be clear to those skilled in the art, after reading this disclosure, how to make and use rail coils **510**-*i*.

[0049] Sled-position sensor **512** is an optical range-finding device on the bottom of missile canister **506**. Sled-position sensor **512** transmits an optical beam at reflector **524**, which is located on the bottom of armature **502**, and determines the position of armature **502** based on the time-of-travel of the reflected optical beam. The position of armature **502** is used by launch controller **104** to sequence current flow in booster coil **514** and rail coils **510-1**, **510-2**, and **510-3**. In some embodiments, the position of armature **502** is used by launch controller **104** to control current flow in sled coil **522**. It will be clear to those skilled in the art, after reading this disclosure, how to make and use sled-position sensor **512** and reflector **524**.

[0050] Referring now to FIGS. **5** and **6**, a representative missile launch sequence is described. At task **601**, weapons control system **106** passes launch authority and target information to launch controller **104**.

[0051] At task **602**, launch controller **104** passes target information to missile **202**.

[0052] At task **603**, power system **108** energizes booster coil **514** with current supplied on current cable **114**. Power system **108** controls the flow of electric current in booster coil **514**, which is substantially immovable with respect to missile canister **506**. The current flow is controlled such that a first electromagnetic force is generated along axis **518** by booster coil **514**. The direction of the generated force is made so as to cause a repulsive force between armature **502** and booster coil **514** that is directed along axis **518**. When the magnitude of the repulsive force exceeds a pre-determined threshold, the sled restraint bolt releases, and armature **502** is allowed to travel along axis **518** toward the muzzle end of launcher **102** and toward the interior volume of rail coil **510-1**. In some alternative embodiments, power system **108** also controls the flow of electric current in sled coil **522**. In some alternative embodiments, the current flow in sled coil **522** is controlled such that a second electromagnetic force is generated along axis **518** so as to increase the force applied to armature **502**. Due to its proximity and orientation with respect to armature **502**, the electromagnetic force generated by booster coil **514** is more efficiently coupled to the armature **502** than the electromagnetic force generated by rail coils in prior art electromagnetic missile launchers.

[0053] At task **604**, as armature **502** travels along axis **518**, power system **108** sequences the flow of current in booster coil **514** and rail coil **510-1** in order to substantially maximize the efficiency of the propulsion of armature **502**. As armature **502** continues its travel along axis **518**, power system **108** sequences the flow of current in rail coils **510-1**, **510-2**, and **510-3** to substantially maximize propulsion of armature **502** toward the muzzle end of launcher **102**. The illustrative embodiment comprises four propulsion coils, booster coil **514**, and rail coils **510-1**, **510-2**, and **510-3**. It will be clear to those skilled in the art, however, after reading this specification, how to make and use alternative embodiments of the present invention that comprise any number of coils that are:

[0054] i. continuous; or

[0055] ii. separate and on any suitable spacing; or

[0056] iii. inter-leaved along the length of guide rail **504**; or

[0057] iv. any combination of i, ii, and iii.

[0058] At task **605**, sled-position sensor **512** transmits a signal to launch controller **104** to indicate that armature **502** is nearing the end of its travel along axis **518**. In response, launch controller **104** changes the flow of electric current in coils **510-1** through **510-3** to begin to decelerate armature **502**.

[**0059**] At task **606**, accelerometer **520** senses the deceleration of armature **502** and provides a signal that is used to (i) actuate the missile restraint bolts, and (ii) initiate ignition of the missile's chemical-propellant engine.

[**0060**] At task **607**, armature **502** throws missile **202** with sufficient velocity that missile **202** obtains aerodynamic flight away from launcher **102**.

[**0061**] At task **608**, the chemical-propellant engine is ignited once missile **202** has achieved sufficient clearance from launcher **102** but before missile **202** has lost aerodynamic stability.

[**0062**] It will be clear to those skilled in the art, after reading this disclosure, how to make and use accelerometer **520**. Furthermore, it will be clear to those skilled in the art, after reading this specification, how to make and use alternative embodiments of the present invention that use other means of initiating ignition of the chemical-propellant engine such as a signal from an altimeter, a timing circuit, a fuse, or signal transmitted to missile **202** from weapons control system **106**.

[**0063**] It is to be understood that the above-described embodiments are merely illustrative of the present invention and that many variations of the above-described embodiments can be devised by those skilled in the art without departing from the scope of the invention. For example, in this Specification, numerous specific details are provided in order to provide a thorough description and understanding of the illustrative embodiments of the present invention. Those skilled in the art will recognize, however, that the invention can be practiced without one or more of those details, or with other methods, materials, components, etc.

[**0064**] Furthermore, in some instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the illustrative embodiments. It is understood that the various embodiments shown in the Figures are illustrative, and are not necessarily drawn to scale. Reference throughout the specification to "one embodiment" or "an embodiment" or "some embodiments" means that a particular feature, structure, material, or characteristic described in connection with the embodiment(s) is included in at least one embodiment of the present invention, but not necessarily all embodiments. Consequently, the appearances of the phrase "in one embodiment,""in an embodiment," or "in some embodiments" in various places throughout the Specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, materials, or characteristics can be combined in any suitable manner in one or more embodiments. It is therefore intended that such variations be included within the scope of the following claims and their equivalents.

What is claimed is:

1. An apparatus comprising:

an outer coil having a longitudinal axis;

an armature comprising an armature coil that is concentric with said outer coil, wherein the outer diameter of said armature coil is smaller than the inner diameter of said outer coil; and

a pilot accelerator for directing a first force on said armature along said longitudinal axis;

wherein a second force on said armature is based on a mutual inductance of said outer coil and said armature coil; and

wherein said first force accelerates said armature from a rest position toward said outer coil so as to increase said mutual inductance.

2. The apparatus of claim 1 wherein said pilot accelerator comprises a booster coil that is concentric with said armature coil, and wherein the outer diameter of said booster coil is less than the inner diameter of said outer coil, and further wherein said booster coil is located behind said rest position.

3. The apparatus of claim 2 further comprising a power system for controlling the flow of electric current through said outer coil, said booster coil, and said armature coil.

4. The apparatus of claim 1 wherein said pilot accelerator comprises a mechanical-energy storage device.

5. The apparatus of claim 1 wherein said pilot accelerator comprises a compressed gas system.

6. The apparatus of claim 1 wherein said pilot accelerator comprises an explosive device.

7. The apparatus of claim 1 further comprising a missile, wherein said missile and said armature are physically-coupled.

8. An apparatus comprising:

an armature for throwing a missile, wherein said armature comprises a first electromagnet;

a guide for propelling said armature, wherein said guide comprises a second electromagnet; and

a pilot accelerator;

wherein a first force on said armature is based on the flow of electric current in said second electromagnet; and

wherein said pilot accelerator exerts a second force on said armature, and wherein said second force accelerates said armature from rest toward said first electromagnet so as to increase the application of said first force on said armature.

9. The apparatus of claim 8 wherein said pilot accelerator comprises a third electromagnet and wherein said third electromagnet has an outer diameter that is less than the inner diameter of said second electromagnet.

10. The apparatus of claim 9 wherein said third electromagnet has an outer diameter that is substantially equal to the outer diameter of said first electromagnet.

11. The apparatus of claim 9 wherein said second force is based on the flow of electric current in at least one of said first electromagnet and said third electromagnet.

12. The apparatus of claim 8 wherein said pilot accelerator comprises a compressed gas system.

13. The apparatus of claim 8 wherein said pilot accelerator comprises an explosive device.

14. An apparatus comprising:

a missile;

an outer coil for applying a first force to an armature for throwing said missile, wherein said outer coil defines a cavity having a cavity diameter, and wherein said first force is based on the flow of electric current in said outer coil;

said armature, wherein said armature comprises a platform and an armature coil that is substantially immovable with respect to said platform, and wherein said armature has a rest position that is at least partially outside said cavity; and

a pilot accelerator for applying a second force on said armature to accelerate said armature from rest toward said outer coil, wherein said pilot accelerator has an outer diameter that is less than said cavity diameter, and wherein said pilot accelerator is fixedly located behind said rest position.

15. The apparatus of claim 14 wherein said first force is based on the mutual inductance of said outer coil and said armature coil.

16. The apparatus of claim 14 wherein said pilot accelerator comprises a booster coil, and wherein said second force is based on the flow of electric current in said booster coil.

17. The apparatus of claim 16 wherein said armature comprises an armature coil, and wherein said second force is based on the mutual inductance of said booster coil and said armature coil.

18. The apparatus of claim 14 wherein said armature comprises an armature coil, and wherein said second force is based on the flow of electric current in said armature coil.

19. The apparatus of claim 14 wherein said pilot accelerator comprises a compressed gas system.

20. The apparatus of claim 14 wherein said pilot accelerator comprises an explosive device.

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