Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

From my perspective

The source and nature of general purpose technologies for supporting next K-waves: Global leadership and the case study of the U.S. Navy's Mobile User Objective System

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ARTICLE INFO

Article history:
Received 13 January 2016
Received in revised form 13 April 2016
Accepted 22 May 2016
Available online xxxx

JEL classification:
O31
O33

Keywords:
General Purpose Technology
Source of technological innovations
Global Leadership
K-waves
MUOS

ABSTRACT

A fundamental problem in the field of the technological studies is to explain the source and nature of general purpose technologies (GPTs) that can support the patterns of long waves and socio-economic progress of nations. The study here confronts this problem by applying the theoretical framework of global leadership-driven innovations, which endeavors to clarify and to generalize whenever possible, the source and nature of a new GPT in a not-too-distant future. This study suggests that one of contributing factors that may support the next GPT is due to strategic investments for the U.S. Navy's Mobile User Objective System (MUOS). This scientific and technological investment for U.S. military has the purpose to reinforce U.S. global leadership and, at the same time, can induce clusters of new technology in society. The MUOS is a constellation of ground-breaking satellites for next-generation narrowband tactical satellite communications system, which makes prior products obsolete (e.g., UHF Follow-On satellites). This technological system and related technological search for U.S. military are developing new information and communications technologies (ICTs) that are bringing the future of worldwide mobile satellite communications into reality. Overall, then, this study shows, by applying a new theory, some invariant factors of the source of GPTs and a possible new technological system for supporting long-run dynamics of current Kondratieff wave and future human development in society.

1. A problem in technology studies: the source and nature of future general purpose technologies (GPTs)

Technological change has a great weight in supporting long waves, economic and social change (Ayres, 1990a,b; Linstone, 2004; Phillips, 2008, 2011; Coccia, 2005a, 2007, 2008a, 2014a,b). A great force of the technical change is new path-breaking innovations, which are due to breakthroughs, learning and cumulative change of specific technical knowledge (Nelson, 2008; Daim et al., 2013; *cf. also*, Cavallo et al., 2014a, 2015). A typology of path-breaking innovation is the General Purpose Technology (GPT)[1]: an enabling technology for a pervasive use in many sectors to foster new products and processes (Helpman, 1998, p. 3; Bresnahan, 2010). The GPTs can generate changes of techno-economic paradigm ("Technological Revolutions"), "affecting many branches of the economy, as well as giving rise to entirely new sectors" (Freeman and Soete, 1987, p. 56; *cf.*, Lipsey et al., 2005; Coccia, 2009b). GPTs are one of contributing factors that supports the "secular process of growth" (Bresnahan and Trajtenberg, 1995, p. 83)[2] and the upturn of Long Waves (LWs) or Kondratieff waves (K-waves; see Ayres, 1990a,b).

In fact, the dynamics of K-waves has been driven, over time, by vital GPTs, such as steam engine and electricity generation (Ayres, 1990a,b), telegraph and telephone (Devezas et al., 2005), radio and TV (Devezas et al., 2005), Internet (Devezas et al., 2005; cf. Ayres, 2005), etc.

In the field of the technological studies a main question is to explain the source and nature of new GPTs and other path-breaking innovations that can cause and sustain K-waves and future economic change in society (Ruttan, 2001, 2006). Scholars suggest some major innovations that may support current and next K-waves, such as molecular technology (Ruttan, 2001; Linstone, 2004), nanotechnology and

☆ I gratefully acknowledge financial support from the CNR - National Research Council of Italy for my visiting at RAND Corporation (Washington office) and at Arizona State University in 2015 (grant 0072373-2014) where this research started. I thank the Library of RAND Corporation, George Mason University (Arlington Campus), Arizona State University and Library of Congress for scientific material provided on these topics. I also thank Richard Silberglitt, Cynthia R. Cook, Howard J. Shatz, S. Berner, T. U. Daim and R. S. Girven for helpful comments and suggestions to this study. This work is the sole responsibility of the author and is not necessarily the opinion of CNR, ASU and RAND Corporation. The author declares that he has no relevant or material financial interests that relate to the research discussed in this paper.

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[1] This study uses interchangeably the concept of GPTs, radical or major innovations to indicate path-breaking innovations.

[2] *cf.* also Helpman (1998), Lipsey et al. (1998), Ristuccia and Solomou (2014).

http://dx.doi.org/10.1016/j.techfore.2016.05.019
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superconductivity (Lipsey et al., 1998), biotechnology and materials science (Linstone and Devezas, 2012), faster than light technologies (Coccia, 2010a), and so on (cf. also Daim et al., 2006, 2009).

However, in economics of innovation, the precise source and nature of new GPTs that may support the current and next K-waves are unknown. This study confronts the problem here by applying a theoretical framework, which endeavors to clarify and to generalize whenever possible, the source and nature of a new GPT in a not-too-distant future. This study can provide useful insights to explain the foundation for and direction of a possible GPT that may support current and next K-waves as well as may sustain future technical progress, economic and social change.

2. Background context of the relation between path-breaking technologies and K-waves for economic and social change

The debate on the theory of Long Waves (LWs) or Kondratieff waves (K-waves) started in 1930s with the empirical evidence of the long-run time series of price levels presented by Kondratieff (1935). K-waves are long-term fluctuations of capitalistic systems that support economic and social change of inter-related nations (Linstone and Devezas, 2012). In particular, K-waves are patterns of 50 to 60 year cycles of recession-depression-recovery-prosperity, which show the economic dynamics of Western economies for the past three hundred years (Coccia, 2010b). This long-run dynamics of economic systems has driven structural changes of economies and shifts of new techno-economic paradigms (Ayres, 1990a,b; Devezas et al., 2005; Coccia, 2010a,b). Modelski (2001, pp. 76–7) claims that:

> The K-wave is a bunching of basic innovations that give rise to leading industrial or commercial sectors, producing S-shaped surges of growth …. K-waves might therefore be defined as processes of the rise and fall of lead sectors, or for short as structural change in the global economy …. The now more widely perceived notion of K-waves as 'gales of creative destruction' paving the way for new technological paradigms …. K-waves are, in the first place, endogenous to the global economy. But, in the second place, they are also interlinked with other subsets of human organization, such as political, social, and cultural, and these must also be explored.

Mensch (1979) showed the relation between the clustering of basic innovations and the evolution of K-waves; in particular, basic innovations are concentrated in the down slope and bottom of the K-wave: the period of "creative destruction" (Devezas et al., 2005, p. 917). The recovery of K-waves is then triggered through the diffusion of basic technology with new radical and incremental innovations, their commercial introduction, and widespread adoption in markets (cf. Linstone and Devezas, 2012; Coccia, 2010a; Korotayev et al., 2011; Marchetti, 1980). The history of technology shows that surges of radical innovations, which arose during the downswing of the 1st K-wave, in 1820–1840, are due to inventions of steam engines, telegraph, steel industry, Portland cement, etc.; clusters of innovations, during the downturn of the 2nd K-wave, in about 1870–1895, are mainly due to the discovery of electricity generation, electromagnetic transmitters and receivers, etc., whereas during the downturn of the 3rd K-wave, in about 1929–1946, main innovations are aircraft, radio and TV, etc. (Ayres, 1990a,b; *cf.*, Basalla, 1988). At the end of the 4th K-wave downswing, the Internet technology was generated and now is embarking on the 5th K-wave upswing for a "consolidation structural cycle" (Devezas et al., 2005, p. 916) and a cascade of innovations in society. However, Ayres (2005, pp. 936–7, original emphasis) argued that:

> The digital revolution has not (yet) exhibited much promise for spillovers that would create enormous new industries, the way electric power and the internal combustion did. … the important spillovers are innovations that have powerful but accidental economic impacts outside the field where the innovation took place …. In summary, I am not persuaded that the internet (or any other significant innovation now on the horizon) is potent enough to trigger a K-wave upswing in the coming years.

Linstone and Devezas (2012, p. 416) suggest that the evolution of basic innovations in nanotechnology, materials science and biotechnology can be the foundation of a molecular age encompassing the 5th K-wave downswing and 6th K-wave upswing, approximately from 2025 to 2080 (*cf. also* Linstone, 2004, pp. 192ff). The convergence of information and molecular research fields[3] can generate new technological pathways and also "Technological Revolutions" in future K-waves (Coccia, 2012, 2012a, 2012b, 2014; Coccia and Wang, 2015, 2016).

In general, a driving force of K-waves is major innovations, such as general purpose technologies (GPTs) that are long-run revolutionary changes of techno-economic paradigm (Freeman and Soete, 1987, pp. 56–57; Bresnahan, 2010, pp. 763–791). These path-breaking innovations are mainly of transformative nature and, by a "destructive creation" (Calvano, 2007), make prior products and knowledge obsolete (*cf. also* Calabrese et al., 2005; Cavallo et al., 2014b). The diffusion of GPTs generates several ripples of effects that permeate the overall structure of the economy, remove barriers and induce corporate, industrial, economic and social change (*cf.*, Coccia, 2005b, 2009; Peirce, 1975; Coccia, 2010c, 2015; Phillips, 2011). In short, the *general purpose technologies are basic components (e.g. transistors in electronics), fundamental technologies for electricity generation and/or general platform (e.g. satellites) for the architecture of various families of new products/processes made and used quite differently. GPTs are a vital technology that improves communications parallel to transportation technology in society.* "GPTs are characterized by pervasiveness, inherent potential for technical improvements, and 'innovational complementarities', giving rise to increasing returns-to-scale . . . such as the steam engine, the electric motor, and semiconductors" (Bresnahan and Trajtenberg, 1995, p. 83, original emphasis; *cf.*, Jovanovic and Rousseau, 2005, p. 1185). The different applications of new GPTs are driven by leading firms to maximize the profit and/or to achieve/exploit the position of a (temporary) monopoly over time (Coccia, 2015). Overall, then, GPTs support K-waves and affect long-run economic and social change (Ayres, 1990a,b). Electricity power and information and communications technologies (ICTs) are regarded as the prototypic general purpose technologies (Jovanovic and Rousseau, 2005). Lipsey et al. (1998, p. 38ff) argue that next GPTs may be biotechnology, superconductivity and nanotechnology. Ruttan (2001, pp. 368–422) claims that molecular biology and biotechnology will represent the major new general purpose technology of the early decades of the 21st century.

However, the analysis of the source and nature of new GPTs is problematic topics because of the uncertain evolution and convergence of major technologies, in the long run, with new and different technologies, which generate unforeseen technological trajectories. Hence, a main question in technological studies is to explain the source, nature and prospects of next GPTs (Ruttan, 2006). Next section confronts this problem here by applying a theory, which endeavors to clarify, as far as possible the source and nature of new GPTs in society.

3. The generalization of Ruttan's studies for the source of GPTs: the theory of global leadership-driven innovations

Ruttan (2006, p. 159ff) argues that the war may be one of contributing factors that generates general purpose technologies (GPTs), because the war induces a high mobilization of scientific, technical, and financial resources in specific environments. In particular, a major war, or threat of a major war, is a critical condition for political institutions of nations (and/or great powers) to commit the huge economic and human resources in sustaining new path-breaking technological trajectories

[3] *cf.* Bainbridge and Roco (2006).

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directed to solve strategic problems (cf., Coccia, 2001, 2006, 2008b, 2009a,b, 2015). As a matter of fact, in the presence of effective and/or potential consequential threats or important opportunities, the great powers (or leading nations) have environmental stimuli to solve relevant problems in strategic fields that sustain new technology because: "the … 'necessity' is the mother of invention" (Ayres, 1998, p. 289, original emphasis).

In brief, Ruttan (2006, p. 184ff) argues that a threat of a major war, combined with other factors, mobilizes the huge human and economic resources that may support the development of GPTs with clusters of innovations. However, the major war seems to be a necessary but not sufficient factor for generating new GPTs (Coccia, 2015, *passim*). In fact, some GPTs have been originated without potential and/or effective conflicts, such as printing press, steam engine, electricity generation, etc. Hence, it is clear that there are at least some facts about the source of GPTs that Ruttan's approach has trouble explaining (Ruttan, 2006).

Coccia (2015) presents a theory (hypothesis of global leadership-driven innovations) that seeks to clarify and generalize, whenever possible, the source of GPTs over time and space.

First of all, several studies have analyzed a wide range of factors that may affect innovative performance of socio-economic systems. Leadership is one of the most important determinants (Jung et al., 2008). West et al. (2003) showed that leadership clarity is associated with innovation in organizations. Instead, Makri and Scandura (2010, pp. 85–86) claimed that the leadership seems to be an important driver of high-tech firm's ability to innovate.

Despite this, nowhere among the highly varied socio-economic studies of technology does one find a general analysis of possible source of GPTs based on the precise role of global leadership of great powers (or leading nations). Coccia's (2015) theory endeavors to explain the general source of GPTs by considering the goal of global leadership of purposeful systems[4]. In particular, purposeful systems (*e.g.*, countries/firms), -with high economic potential and purposeful elements having the *purpose* of achieving/sustaining a global leadership-, can engender GPTs (or major innovations) to cope with consequential environmental threats and/or to take advantage of important opportunities. The long-run diffusion of GPTs is performed by means of processes of socio-economic influence of global leaders on wide geo-economic areas.

The theory of global leadership-driven innovations by Coccia (2015) is underpinned in the philosophy of science of the teleology, which stresses the importance of the concept of purpose for the behavior of natural (and social) events (Rosenblueth et al., 1943; cf., Churchman and Ackoff, 1950). Some key concepts, which underpin the theory of global leadership-driven innovations, are (Coccia, 2015):

- Leadership is a system of relationships that involves the power in varying degrees within and between organizations.
- A purposeful organization is a complex system with high economic potential and purposeful elements that have a common purpose of global leadership.
- A great power is a purposeful organization with economic war potential having the purpose of global leadership.
- The global leadership involves a process of influence of a purposeful organization with high economic war potential - worldwide recognized - on (wide) geo-economic areas (*cf. also* Mendenhall et al., 2012, p. 500; Mendenhall and Bird, 2013).
- GPTs can be a technological platform for supporting various families of new products/processes that improve communications and transportation technology.

The hypothesis of global leadership-driven innovations is:

The source of general purpose technologies and higher technological performances is positively affected by the purpose of achieving/sustaining the global leadership of a purposeful system with high economic potential.

In general, this theoretical framework hypothesizes that a great power with high economic-war potential applies a strategy of high investments in human and economic resources to cope with effective and/or potential environmental threats to national security or to take advantage of important opportunities (*e.g.*, high military R&D during conflicts or period of tension). These strategic investments of great powers support the development of new technology (*e.g.*, new GPTs and/or radical innovations) in order to solve relevant problems[5] directed to achieve/sustain/defend the global leadership and national security (Coccia, 2015).

In short, GPTs are new technology naturally directed to solve critical problems for supporting competitive advantages of global leaders in the presence of consequential environmental threats and/or important opportunities. GPTs induce, in the long run, clusters of radical and incremental innovations technically and economically inter-related for vital changes of techno-economic paradigm in society. This theoretical framework of global leadership-driven innovations can be schematically summarized in Fig. 1.

A main psychological factor, underlying the linkages presented in Fig. 1, can be also the fear in society, during a period of political and/or military tension, which leads the human being and their institutions to react with a behavior of adaptation and learning to cope with consequential environmental threats.

This behavior of adaptation of leading nations, in certain environments and periods, seems to induce new technological innovations.[6] The historial evidence of this theory is by instantiating the source of different GPTs with the purpose of global leadership of great powers (and/or societies) on wide geo-economic areas over time (Coccia, 2015), such as: the wheel used by Sumerian army, a new technology for winning wars and achieving the purpose of the leadership in the geographical area of Mesopotamia (about 5th to 3rd millennia BCE in the Middle-East Europe), roads and bridges (and other major innovations in construction technology) by Roman army to support the Roman Empire (from 27 BCE to 470 CE), print press technology by Roman Catholic Church to affirm its religious power in Europe (over 1430–1500), steam engine and electricity generation during the British Empire to reinforce its geo-economic power and leadership against France and other nations (about 1760 onwards), computer, satellites, and other ICTs by U.S.A. to sustain its global leadership during several conflicts/environmental tensions over time (from 1945). These major inventions and their innovations have played a main role for the evolution of K-waves and human society over time (Ayres, 1990a,b; Devezas et al., 2005; Coccia, 2010b). In short, the hypothesized purpose of achieving/sustaining the global leadership by purposeful nations/organizations/societies is basic to generate vital GPTs as showed in the history of technology.

To sum up, some natural characteristics of GPTs are that (Coccia, 2015):

– GPTs are generated by a society with high economic war potential during a struggle to prove military strength and/or scientific/technological superiority *vs.* (i.e., against) other competitors (*e.g.*, belligerent nations) in order to achieve and/or sustain the purpose of

[4] A *purposeful system* is one which can produce the same outcome in different ways in the same (internal or external) state and can produce different outcomes in the same and different states (Ackoff, 1971, p. 666, original emphasis); the *objective* of a purposeful system in a particular situation is a preferred outcome that cannot be obtained within a specified period but which can be obtained over a long time period (Ackoff, 1971, p. 667, original emphasis). A purposeful system can be a country, firm, institution, *etc.*

[5] Usher (1954) explains the evolution of new technology with four concepts (*see* Basalla, 1988, p. 23): 1) Perception of the problem: an incomplete pattern in need of resolution is recognized; 2) setting stage: assimilation of data related to the problem; 3) act of insight: a mental act finds a solution to the problem; 4) critical revision: overall exploration and revision of the problem and improvements by means of new acts of insight.

[6] For instance, Koh (2007) argues that the current fair in society against terrorism of radical Islamism will affect patterns of technological innovations to develop new technology in order to cope with activities of terrorists and combat international terrorism.

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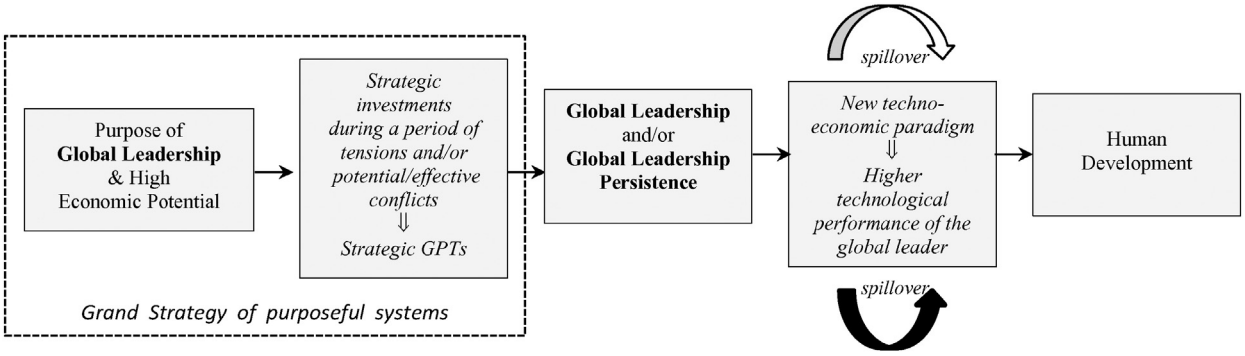

Fig. 1. Theory of global leadership-driven innovation for explaining the source of GPTs (Coccia, 2015).

global leadership;
- GPTs solve relevant problems to cope with consequential threats to national security and/or to take advantage of important environmental opportunities in the presence of political and/or military tensions among belligerent organizations/nations/societies;
- GPTs generate a "destructive creation" (Calvano, 2007, passim) of current products/processes and make prior technical knowledge obsolete;
- GPTs affect many branches of the economy, as well as communications and transportation technology, and give rise to entirely new sectors, supporting K-waves and long-run human development in society.

In short, the source of GPTs seems to be driven by great powers to solve relevant and strategic problems in the presence of consequential environmental threats to national security, to achieve/sustain/defend the position of global leadership (*e.g.*, major innovations have been originated during the struggle -with military and political tensions-between U.S. and Soviet Union in the 1960s to prove scientific and technological superiority/leadership, and military strength in space). Overall, then, the historical evidence seems in general to support the hypothesis above that the source of general purpose technologies can be explained by the *purpose of global leadership* of purposeful organizations with high economic (and military) potential (e.g. great powers), rather than (effective/potential) warfare *per se*. The theoretical framework of global leadership-driven innovations (Coccia, 2015) generalizes the Ruttan's approach (Ruttan, 2006), which seems to be a specific case of this general theory.

The hypothesis of global-leadership driven innovations is an appropriate approach to analyze basic determinants for emerging GPTs that can support K-waves and economic change. We now move on to apply this theory, trying, as far as possible, to clarify the source and nature of a possible GPT for current and next K-waves.

4. The source and nature of a new GPT: the U.S. Navy's Mobile User Objective System (MUOS)

The theoretical framework presented in previous section is applied to explain the source of a new technological system[7] that may lay the foundations for a possible GPT to support K-waves in a not-to-distant future.

As said, leading nations perform strategic investments to solve relevant problem directed to cope with consequential environmental threats and/or to take advantage of important opportunities in order to achieve/sustain the purpose of global leadership. Table 1 shows that the USA, a global leader (Modelski, 2010; Ferguson, 2010), has levels of average military expenditure as percentage of gross domestic product (GDP), R&D intensity, patents applications and GDP per capita higher than other leading countries. The high levels of these main indicators in the USA indicate a strong national system of innovation (cf., Coccia, 2012c, 2015; Mokyr, 2002).

Currently, the USA is also performing strategic investments for establishing a new (military) technological system directed to reinforce its economic war potential and global leadership: The U.S. Navy's Mobile User Objective System (MUOS), which is a constellation of ground-breaking satellites. The strategic project is valuated at a high cost of about $7345.9M over it lifespan, which could run through 2024 (GAO, 2013).

These strategic (military) investments can induce a general purpose technology (GPT) and clusters of radical and incremental innovations in society. As a matter of fact, the U.S. Navy's Mobile User Objective System (MUOS) is a next-generation narrowband tactical satellite communications system designed to significantly improve ground communications for U.S. forces on the move in order to make war fighters safer and more effective. MUOS will provide to military users more communications capability over existing systems, including simultaneous voice, video and data. MUOS users will be able to talk, text and transfer data almost anywhere around the world on a high-speed internet protocol-based system[8] (Fig. 2; Lockheed Martin, 2016; *cf.*, The Navy Communications Satellite Program Office, 2014a, b).

The MUOS replaces the seven Ultra High Frequency System Follow-On (UFO) satellites that were launched between 1993 and 2003 (NASA, 2015). This ground-breaking communications system (MUOS) would provide ten times more throughput (or volume of information that can be transmitted) than current UFO system (300 MHz to 3 GHz frequency range). MUOS, -with a complex software to manage the network and a Wideband Code Division Multiple Access waveform that serves as an interface for end-user radios-, can provide higher tactical mobile communications capabilities to smaller terminals for supporting U.S. military (NASA, 2015). In short, new MUOS technology can connect radio terminal users wherever they are, with high data rates and an improved operational availability also in extreme and disadvantage situations due to weather, environmental and flora constraints (The Navy Communications Satellite Program Office, 2014a,b; Lockheed Martin, 2016).

Fig. 3 shows the space platform of MUOS, which is based on a constellation of five planned communications satellites (four operational satellites with one on-orbit spare). The first MUOS satellite, MUOS-1, was launched into space successfully in 2012. MUOS-2 was launched in 2013. The U.S. Navy and Lockheed Martin in 2015 launched the MUOS-3 and MUOS-4. Although MUOS is not yet complete, the satellite MUOS-4 has given to this new technological system a worldwide coverage for the first time. The final satellite MUOS-5 is intended to serve as an on-orbit spare and will be scheduled for launch in 2016 (Lockheed

[7] Keirstead (1948) introduced the concept of 'constellations' of innovations, which were technically and economically inter-related. These clusters of radical and incremental innovations are described by Freeman and Soete (1987, p. 56) as 'new technological systems'.

[8] The current technology only allows users to "talk" if they are "under" the same satellite (Lockheed Martin, 2016).

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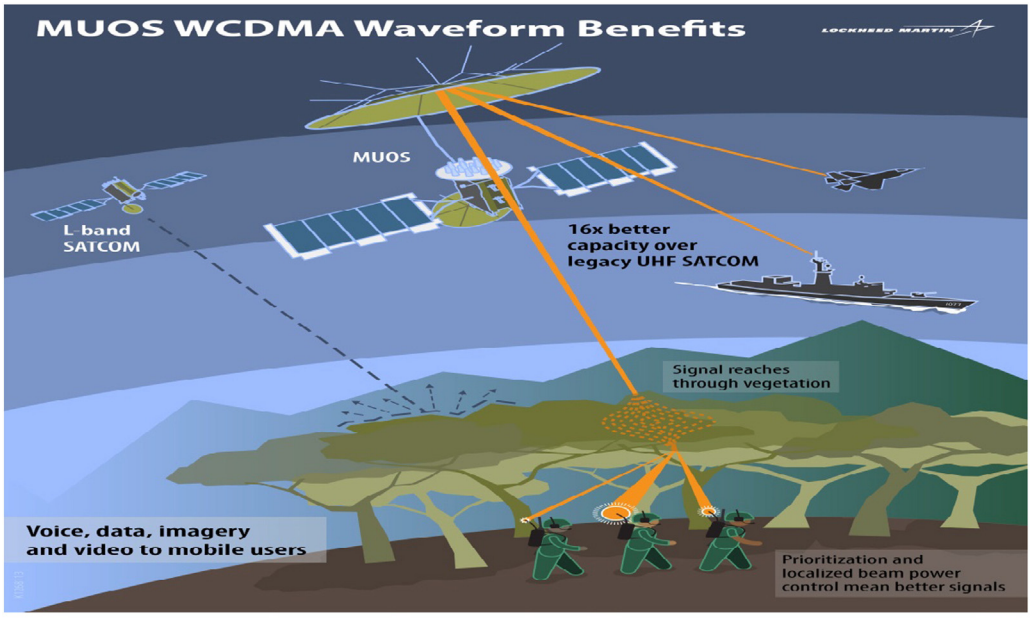
Table 1
Technological and economic performances of some leading countries.

Countries	Average military expenditure as % of GDP 1992–2013(a)	Average R&D expenditure (% of GDP) 1996–2005(b)	Average patent applications, residents per million people 1985–2005(b)	Average GDP per capita, PPP (constant 2005 international $) 1989–2006(b)
United States	**3.90**	**2.66**	**447.20**	**36,318.11**
Russia	3.87	1.09	145.84	9828.36
France	2.64	2.18	224.04	27,439.67
UK	2.60	1.82	334.51	26,565.94
China P.R.	1.99	0.92	18.00	2398.01

Note: In **bold** high performances.
(a) SIPRI Military Expenditure Database (2012).
(b) World Bank (2008).



Source: Lockheed Martin (2016).

Fig. 2. Simultaneous communications system of MUOS based on high ICTs. *Source*: Lockheed Martin (2016).

Martin, 2016). The constellation of these satellites is expected to be fully operational in 2018 or thereabouts (NASA, 2015).

MUOS also comprises a network management system with four ground stations, each of which serves one of the four active satellites, located at (Fig. 3): the Australian Defence Satellite Communications Station at Kojarena (Geraldton, Western Australia); Naval Radio Transmitter Facility close to Naval Air Station Sigonella (Sicily, Italy); Naval SATCOM Facility, Northwest Chesapeake (Southeast Virginia); and the Naval Computer and Telecommunications Area Master Station Pacific (Hawaii). Hence, the United States has the worldwide political and economic power and a global network of socio-economic relationships to support the creation of this new constellation of satellites and large radar ground stations overseas (*i.e.*, in Australia and Italy). MUOS is called "cell towers in space" for their ability to deliver the kinds of communications consumers expect on Earth (Fig. 4).[9] Navy Capt. Joseph Kan, the MUOS program manager, states that: "The Navy, in close collaboration with the Army, Air Force and our industry partners, is bringing the future of worldwide mobile satellite communications into reality for the United States and potentially allied nations" (as quoted by Davis, 2014).

Overall, then, U.S. scientific and technological investments are creating the MUOS to sustain the incumbent position of global leadership. This GPT may be basic for new information and communications technologies (ICTs) that support current and next K-waves, as well as economic and social change.

5. Discussion

Why may MUOS platform and related scientific/technological search lay the foundations for a possible GPT for current and future K-waves?

Firstly, GPTs are originated by global leaders and MUOS is planned by a global leader: the USA. In fact, the United States is creating a new ground-breaking mobile communications satellites designed to provide tactical mobile communications to the U.S. military for strategic activities worldwide. The high mobilization of scientific, technical, and financial resources for MUOS is generating advanced information and communications technologies (ICTs) that may be the source of a cascade of innovations in current and future K-waves. Hence, next GPT may be based on a vital cumulative change of technological innovations in ICTs. This new technical knowledge for creating MUOS seems to be driven mainly by the U.S. goal to support the national security, the global leadership, and the stability of world geo-political equilibria.

Secondly, a main characteristic of GPTs is to improve communications systems (Coccia, 2005b, pp. 123–124). The history of technology shows that GPTs enhance communications systems and parallel transportation technology (Coccia, 2015; Singer et al., 1956). In effect, MUOS is creating a strategic platform of telecommunications based on innovative cellular

[9] This Navy's powerful communications satellite system is also presenting some problems of aligning the deployment of spacecraft with the development of their Earth-bound terminals and ground stations (National Defense, 2015). The solution of these supplementary technological problems can induce acts of insight to support further patterns of new technological innovations.

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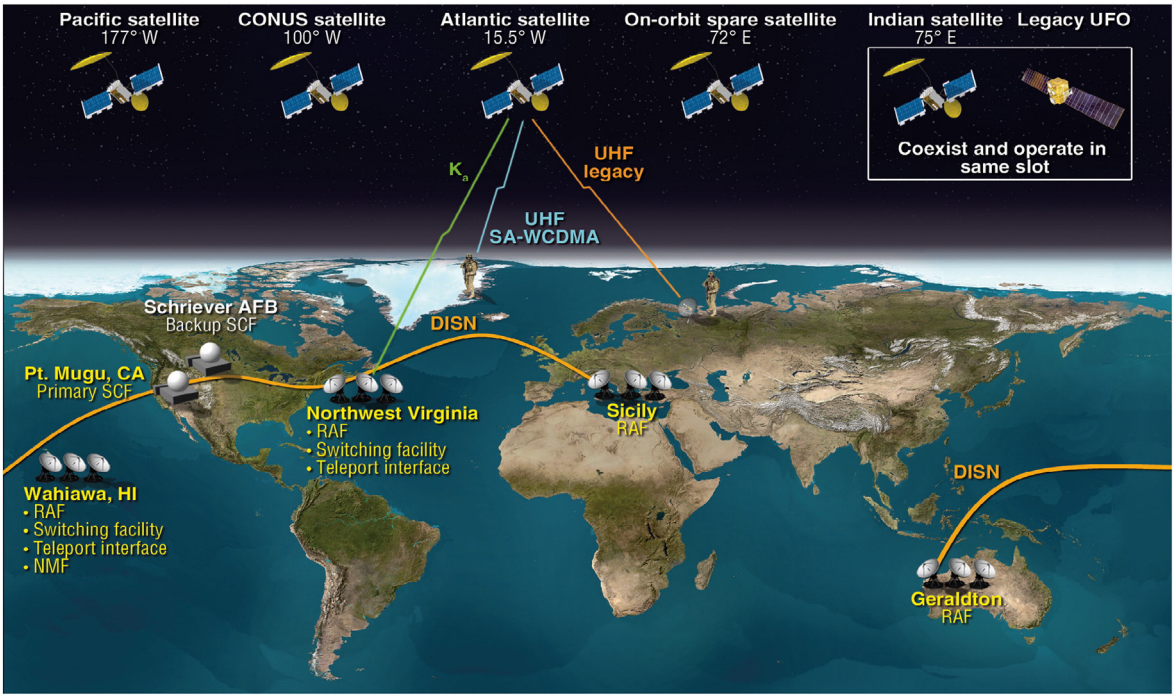
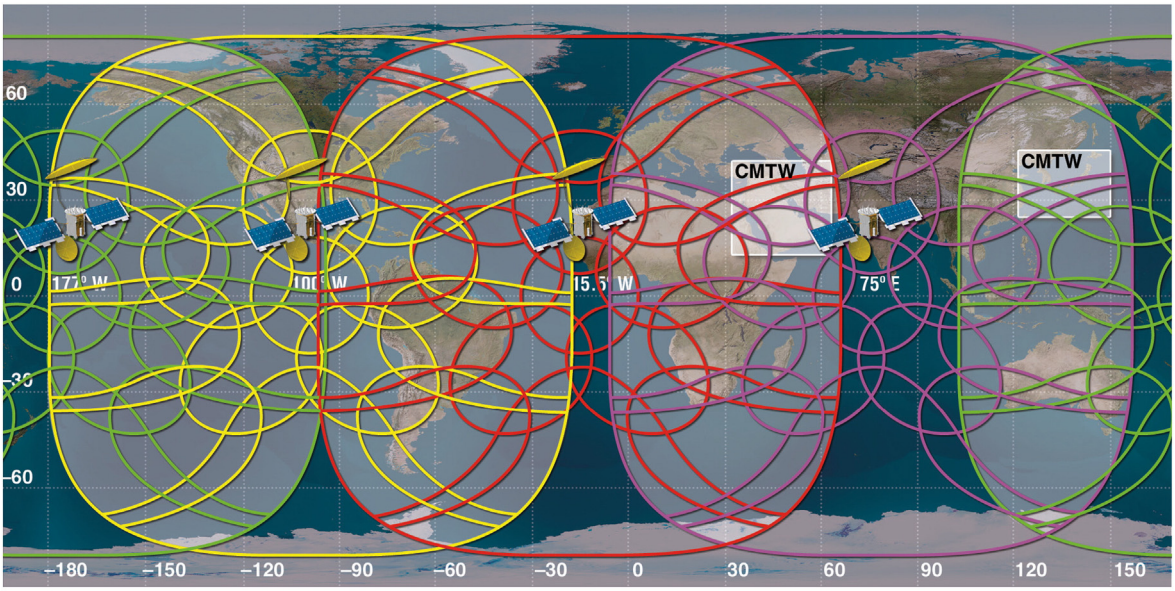


Source: Oetting J. D. and Tao J. (2011, p. 104).

Fig. 3. MUOS architecture. *Source*: Oetting and Tao (2011, p. 104).

phone network architecture of communications in combination with geo-synchronous satellites. This next-generation of worldwide mobile satellite communications planned for U.S. military can support clusters of innovations in ICTs and wireless technology in society. Users with MUOS can transmit and receive high-quality, prioritized voice and data on a high-speed internet protocol-based system. Moreover, MUOS may help solve communication challenges in several civil and scientific activities, such as it has recently provided communications during an Antarctic resupply mission. Demonstrations show that MUOS satellite signal can reach far into the arctic with important advantages to increase in shipping, resource exploration and tourism in future (Lockheed Martin, 2016). Overall, the U.S. is performing strategic investments to construct a ground-breaking mobile satellite communications system for military purposes (to cope with consequential environmental threats to its national security and defend its incumbent global leadership) that can induce better, safer and faster communications in future society. This GPT may open new frontiers for human development.

Thirdly, GPTs have a "destructive creation" force (Calvano, 2007, passim) of current products/process and make prior scientific and technical knowledge obsolete. MUOS has this feature because will replace the UHF Follow-On (UFO) satellites, providing ten times more throughput (or volume of information transmitted) of previous system



Source: Oetting J. D. and Tao J. (2011, p. 106).

Fig. 4. MUOS global coverage. *Source*: Oetting and Tao (2011, p. 106).

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(NASA, 2015). Therefore, this new technological system (MUOS) can generate clusters of new radical and incremental innovations of ICTs in the future horizon of societies.

Finally, MUOS provides a critical technological platform in ICTs and seems to meet the criteria of GPTs described by Lipsey et al. (1998), Jovanovic and Rousseau (2005), Ruttan (2006), Bresnahan (2010), Bresnahan and Trajtenberg (1995). Hence, MUOS technology seems to have several analogies with previous GPTs discussed by Singer et al. (1956), Lipsey et al. (1998) and Coccia (2015).

To sum up, the main characteristics of the MUOS are that may:

- improve information and communications technologies (ICTs), parallel to transportation technology
- generate a "destructive creation" of current products/process and make prior scientific/technical knowledge obsolete
- induce clusters of radical and incremental innovations in ICTs and wireless technology
- support corporate, industrial and economic change in current and next K-waves
- construct a long-run communications platform for human evolution and development in society.

In short, this case study of MUOS technology seems to confirm that a vital determinant of general purpose technologies is due to strategic activity of purposeful organizations (*e.g.*, great powers) with high economic (and military) potential to support the purpose of global leadership (Coccia, 2015; *cf.*, Thompson, 2010). As a matter of fact, great powers (e.g., the USA) with high economic-war potential and the objective of global leadership invest economic and human resources for solving strategic problems directed to cope with (effective/potential) consequential environmental threats and/or to take advantage of important opportunities. These strategic investments can induce vital inventions, innovations and lay the foundations for possible GPTs, which support long-run dynamics of K-waves, economic and social change.

Hence, as hypothesized by Coccia (2015), the purpose of global leadership of great powers seems to be an invariant and regular force of the source and evolution of GPTs over time and space. Fig. 5 summarizes the association between global leadership of great powers and source of GPTs over time.

6. Concluding observations

The main aim of this article is to clarify that the purpose of global leadership of great powers, combined with other socio-economic factors in specific environments, can be the source of GPTs and clusters of radical and incremental innovations. This study shows that the U.S. is investing a huge amount of economic and human resources in a ground-breaking communications system to reinforce its economic-war potential: the U.S. Navy's Mobile User Objective System (MUOS), which is a constellation of ground-breaking satellites for next-generation narrowband tactical satellite communications system. In particular, the MUOS is an innovative cellular phone architecture of communications, with main characteristics of GPT that might support a cascade of new technological innovations in future. Especially, MUOS with its high-speed internet protocol-based system and Wideband Code Division Multiple Access capability may support human development, economic and social change. For instance, the demonstrations in polar regions show effective communications by using MUOS technology with vital advantages for commercial shipping, natural resource exploration, scientific studies and also tourism in future (Lockheed Martin, 2016). The MUOS may spread with successive "ripples of effects" (Peirce, 1975) in a not-to-distant future to support economic and social change, and next K-waves.

Nevertheless, Lipsey et al. (1998, p. 44ff) argued the limited predictability of GPTs that is general and not precise because of several socio-economic factors that generate an uncertain evolution of technological paradigms and trajectories. The limited predictability of GPTs is also due to their technological characteristics, which are mainly time and context dependent. In fact, the evolution of GPTs is a difficult technological forecasting due to uncertain convergence with different and interrelated technologies over time. Rosegger (1980, p. 312) claimed that: "Even careful forecasts … likely economic effects of major innovations are bound to be wide of the mark to the extent that these produce totally unpredictable technical and social results or changes in public attitudes".

Overall, then, the source and nature of next GPTs are hardly known in science and technology studies, since we know that other things are often not equal over time and place. Wright (1997, p. 1562) properly asserted that: "In the world of technological change, bounded rationality is the rule". This study clarifies one of invariant factors that can support the source and nature of new GPTs: *i.e., the purpose of global*

PAST/CURRENT PERIOD-UNTIL 2016					FROM 2016-FORECAST HORIZON	
1st K-wave *1780–1838*	**2nd K-wave** *1839–1892*	**3rd K-wave** *1893–1945*	**4th K-wave** *1946–1992*	**5th K-wave** *1992–2045*	**6th K-wave** *2046–2100*	**7th K-wave** *2101–2156*
Global Leadership **British Empire**	Global Leadership **British Empire**	Global Leadership **British Empire/USA**	Global Leadership **USA**	Global Leadership **USA**	**Possible U.S. Global Leadership**	**Possible U.S. Global Leadership**
duration ~330-years of the British Empire (~1583–1914) [a]			**duration to date ~102-years of the U.S. leadership (~1914–2016)**		Possible U.S. global leadership	
PERIOD: 1770S–1910S GENERAL PURPOSE TECHNOLOGY Industrial Revolutions by Steam Engine and Electricity (Locomotive, Steamboat, Electric Plants, etc.)			**PERIOD: 1910S–2010S GENERAL PURPOSE TECHNOLOGY New synthetic materials, new Information and Telecommunications technology: Telephone, Radar, Computer, Satellites, Internet, Wireless Technology, etc.**		**PERIOD: 2010S–2100S GENERAL PURPOSE TECHNOLOGY ICTs and nanotechnology, MUOS and clusters of converging nano-bio-info-cogno innovations**	**PERIOD: 2100S - GENERAL PURPOSE TECHNOLOGY Possible applications of Faster than light Technologies, Technology of elementary particles [b] and gravitational waves**

Note: (a) A cycle is the duration (in years) from the start to the decline of a global leadership (in general a long-run period); this cycle induces changes in the techno-economic paradigm and also likely (irregular) K-waves; (b) *cf.* Coccia (2010b)

Fig. 5. Global leadership-driven evolution of GPTs for the dynamics of K-waves.

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leadership of great powers. However, the conclusions here are, of course, tentative. Most of the focus is on some vital determinants of GPTs, clearly important, but not sufficient for broader understanding and accurate forecasting of the terra incognita of the source of GPTs that will support future K-waves in society.

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